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AIN SHAMS UNIVERSITY
FACULTY OF SCIENCE

AIN SHAMS SCIENCE BULLETIN

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1962

PUBLISHED BY THE FACULTY OF SCIENCE
AIN SHAMS UNIVERSITY, CAIRO

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ON THE RECIPROCAL MATRIX OF AN ALGEBRAIC ROW-FINITE MATRIX. I

By

RAGY H. MAKAR and HEKMAT M. SAKR

An infinite matrix A is said to be self-associative when the power matrix A^r exists for every positive integer r, and has a unique matrix value independent of the order of multiplication of the factors.

An infinite matrix A is said to be algebraic if it is self-associative and satisfies a matrix equation of the form :

$$(1) \qquad a_0 I + a_1 X + a_2 X^2 + \dots + a_m X^m = 0,$$

where the coefficients a_r, $o \leqslant r \leqslant m$, are complex scalars, and I and 0 are the infinite unit matrix and the infinite zero matrix respectively [3]. When this matrix equation is the equation of least degree satisfied by A, A is said to be algebraic of degree* m. Such equation, of least degree, is obviously unique and is called the minimal aquation of A. In place of (1), we usually write the minimal equation of A as :

$$(2) \qquad a_0 I + a_1 A + a_2 A^2 + \dots + a_m A^m = 0.$$

When a class F of infinite matrices contains the scalar matrices, and is closed under finite sum and finite product, then F is called a field. Field so defined for infinite matrices is not the same as field defined in the algebraic sense in works on modern algebra, in that an infinite matrix may have no inverse element. Evidently polynomials in a self-associative matrix A form a field. This field is usually called the field P_A .

---

* We use the term "degree" instead of the term "order" used by Makar (3).

Makar [2,3] has given the following result.

Lemma : Let **A** be an algebraic matrix and let its minimal equation be that in (2). Then a necessary and sufficient condition for **A** to have a reciprocal A^{-1} in P_A is that $a_0 \neq 0$. When this reciprocal exists, it is an algebraic matrix of the same degree as **A**.

In fact when $a_0 \neq 0$, the reciprocal matrix of **A**, in P_A is

$$A^{-1} = -\left\{a_1 I + a_2 A + a_3 A^2 + \ldots + a_m A^{m-1}\right\} / a_0 \tag{3}$$

and the minimal equation of this reciprocal is

$$a_0 (A^{-1})^m + a_1 (A^{-1})^{m-1} + \ldots + a_m I = 0. \tag{4}$$

An infinite matrix **A** in which the number of non-zero elements in each row is finite is called row-finite matrix. With the ith row, $i = 1, 2, 3, \ldots$ of a row-finite marix $A = [\, a_{ij} \,]$ we can associate a number α (i) such that

$$\begin{cases} a_{ij} \neq 0 \text{ for } j = \alpha(i), \\ a_{ij} = 0 \text{ for all } j > \alpha(i). \end{cases} \tag{5}$$

α (i) is an unbounded function of i, as i increases to infinity; otherwise the matrix A is a row-bounded matrix.

When $A = [\, a_{ij} \,]$ is an algebraic row-finite matrix, whose minimal equation involves a scalar matrix term so that **A** has a reciprocal $B = [\, b_{ij} \,]$ in the field P_A, this reciprocal which is already known to be algebraic is a row-finite matrix. This is due to the fact that row-fintite matrices form a field of which P_A is a subfield. The matrix B being row-finite, we can associate with its, i^{th} row, $i = 1, 2, 3, \ldots$ a number β (i) such that

$$\begin{cases} b_{ij} \neq 0 & \text{for } j = \beta(i), \\ b_{ij} = 0 & \text{for all } j > \beta(i). \end{cases} \tag{6}$$

It is interesting to study the growth of β (i) in connection with the growth of α (i).

Theorem I: Let $A = [\, a_{ij} \,]$ be an aigebraic row-finite matrix of degree m, having a reciprocal $B = [\, b_{ij} \,]$ in P_A, and let

$$(7) \qquad \overline{\lim_{i \to \infty}} \frac{\alpha(i)}{i^{\alpha}} = p \,, \qquad o < p < \infty \,,$$

where α is some number > 1, then

$$(8) \qquad \overline{\lim_{i \to \infty}} \frac{\beta(i)}{i^{\alpha^{m-1}}} \leqslant p^{1+\alpha+\alpha^2+\ldots+\alpha^{m-2}} \,,$$

the sign of equality may take place.

Since A is an algebraic matrix of degree m, having a reciprocal B in P_A, the minimal equation of A must be of the form (2), where a_o and a_m are both non-zero scalars. This minimal equation, when multiplied by $B = A^{-1}$, gives

$$(9) \qquad B = b_0 I + b_1 A + b_2 A^2 + \ldots + b_{m-1} A^{m-1} \,.$$

Hence, writing $A^r = [\, \overset{(r)}{a}_{ij} \,]$, we have

$$(10) \qquad b_{ij} = b_0 \delta_{ij} + b_1 a_{ij} + b_2 \overset{(2)}{a}_{ij} + \ldots + b_{m-1} \overset{(m-1)}{a}_{ij}$$

From (7), for any arbitrary $p' > p$, we can find i_0 such that $\alpha(i) < p' i^{\alpha}$ for all $i \geqslant i_0$. Hence we can find i' sufficiently large so that

$$(11) \qquad \begin{cases} \alpha(i) < p' i^{\alpha} & \text{for all } i \geqslant i' \\ \alpha(i) < p' i'^{\alpha} & \text{for all } i < i' \,. \end{cases}$$

Also since $p' > o$ and $\alpha > 1$ we can take i' such that

$$(12) \qquad p' i'^{\alpha} > i'$$

and a fortiori

(13) $$p'i^{\alpha} > i' \qquad \text{for all } i \geqslant i'$$

If we associate with the $i^{\underline{th}}$ row of A^r the number $\overset{(r)}{\alpha}(i)$ corresponding to the number $\alpha(i)$ associated with the $i^{\underline{th}}$ row of A, it follows from the equality

(14) $$\overset{(2)}{a}_{ij} = \sum_{k=1}^{\alpha(i)} a_{ik}\, a_{kj}$$

together with (11) and (13) that

(15) $$\overset{(2)}{\alpha}(i) < p'(p'i^{\alpha})^{\alpha} = p'^{1+\alpha}\, i^{\alpha^2}, \quad \text{for all } i \geqslant i'$$

Also, from (12)

$$p'(p'i'^{\alpha})^{\alpha} > p'i'^{\alpha} > i'$$

so that

(16) $$p'^{1+\alpha}\, i^{\alpha^2} > i' \qquad \text{for all } i \geqslant i'$$

From the equality

(17) $$\overset{(3)}{a}_{ij} = \sum_{k=1}^{\overset{(2)}{\alpha}(i)} \overset{(2)}{a}_{ik}\, a_{kj}$$

together with (11), (15) and (16) it follows that

(18) $$\overset{(3)}{\alpha}(i) < p'(p'^{1+\alpha}\, i^{\alpha^2})^{\alpha}$$

$$= p'^{1+\alpha+\alpha^2}\, i^{\alpha^3} \text{ for all } i \geqslant i'$$

It is seen that, in general,

(19) $$\overset{(r)}{\alpha}(i) < p'^{1+\alpha+\alpha^2+\ldots+\alpha^{r-1}}\, i^{\alpha^r}, \text{ for all } i \geqslant i'.$$

It follows immediately from (10) that

(20) $\beta(i) < p'^{1+\alpha+\alpha^2+\ldots+\sigma^{m-2}}\, i^{\alpha^{m-1}}$ for all $i \geqslant i'$.

Hence

(21) $$\overline{\lim_{i \to \infty}} \frac{\beta(i)}{i^{\alpha^{m-1}}} \leqslant p'^{1+\alpha+\alpha^2+\ldots+\alpha^{m-2}}$$

Since p' is arbitrarily chosn greater than p, we have the required result in (8).

The fact that the sign of equality, in (8), may take place will be illustrated by an example.

Another interesting result is the following.

Theorem II : Let $A = [a_{ij}]$ be an algebraic row-finite matrix of degree m, having a reciprocal $B = [b_{ij}]$ in P_A, and let

(22) $$\overline{\lim_{i \to}} \frac{\log \alpha(i)}{\log i} = \alpha < \infty,$$

Then $\alpha \geqslant 1$, and

(23) $$\frac{1}{\alpha^{m-1}} \leqslant \overline{\lim_{i \to \infty}} \frac{\log \beta(i)}{\log i} \leqslant \alpha^{m-1}$$

the signs of equality may take place.

We first show that if $\alpha < 1$ in (22) then the reciprocal matrix B does not exist.

Considering (22) with $\alpha < 1$, the inequality

$$\overline{\lim_{i \to \infty}} \frac{\log \alpha(i)}{\log i} < 1$$

shows that we can find i' sufficiently large so that

$\alpha(i) < i$ for all $i \geqslant i'$,

$\alpha(i) < i'$ for all $i < i'$

The equality (14) then simply gives

$$\overset{(2)}{\alpha}(i) < i \qquad \text{for all } i \geqslant i'$$

Again the equality (17) simply gives

$$\overset{(3)}{\alpha}(i) < i \qquad \text{for all } i \geqslant i',$$

and so on. Thus we have

$$\overset{(r)}{\alpha}(i) < i \qquad \text{for all } i \geqslant i',\ r = 1,2,3, \ldots, m,$$

whatever be the integer m. Hence an identity of the form

$$a_0 I + a_1 A + a_2 A^2 + \ldots + a_m A^m = O$$

where m is some positive integer, cannot exist unless $a_0 = o$ as the function $\overset{(o)}{\alpha}(i)$ for the matrix I ($= A^0$ conventionally) is such that $\overset{(o)}{\alpha}(i) = i$ for $i = 1, 2, 3 \ldots$. In other words if A is algebraic, its minimal equation does not involve a scalar matrix term and consequently, by the above lemma, it has no reciprocal B in P_A. Thus $\alpha \geqslant 1$.

Now for any arbitrary $\alpha' \geqslant \alpha$, we can find i' sufficiently large such that.

$$(24) \qquad \begin{cases} \alpha(i) < i^{\alpha'} & \text{for all } i \geqslant i' \\ \alpha(i) < i'^{\alpha'} & \text{for all } i < i' \end{cases}$$

Noting that $\alpha' > 1$ (being $> \alpha$), and comparing (24) with (11) we get as in (20)

$$\beta(i) <_i \alpha'^{m-1} \qquad \text{for all } i \geqslant i'$$

Hence

$$\overline{\lim_{i \to \infty}} \frac{\log \beta (i)}{\log i} \leqslant \alpha'^{m-1}. \tag{25}$$

Since α' is arbitrarily chosen greater than α. we must have

$$\overline{\lim_{i \to \infty}} \frac{\log \beta (i)}{\log i} \leqslant \alpha^{m-1}. \tag{26}$$

Now, as we already know, B is algebraic of degree m, and its minimal equation is

$$a_m I + a_{m-1} B + a_{m-2} B^2 + \dots + a_0 B^m = 0. \tag{27}$$

when multiplied by $B^{-1} = A$, this last equation gives

$$A = c_0 I + c_1 B + c_2 B^2 + \dots + c_{m-1} B^{m-1}, \tag{28}$$

and assuming that

$$\overline{\lim_{i \to \infty}} \frac{\log \beta (i)}{\log i} = \beta < \infty \tag{29}$$

a treatment similar to that given above shows that $\beta > 1$ and that

$$\alpha \leqslant \beta^{m-1} \tag{30}$$

This completes the proof of the required result in (23).

The fact that the signs of equality in (23) may take place will be illustrated by an example.

Another result which is equally interesting to that in theorem II is the following.

Theorem III : Let $A = [a_{ij}]$ be an algebraic row-finite matrix of degree m, having a reciprocal $B = [b_{ij}]$ in P_A, and let

$$\overline{\lim_{i \to \infty}} \frac{\alpha (i)}{i} = \alpha < \infty. \tag{31}$$

Then $\alpha \geqslant 1$ and

$$(32) \quad \alpha^{1/(m-1)} \leqslant \overline{\lim_{i \to \infty}} \frac{\beta(i)}{i} \leqslant \alpha^{m-1} ;$$

the signs of equality may take place.

The upper and lower bounds in this theorem can be grasped through the literature on algebraic basic sets of polynomials [1, pp.307 - 308 and p. 313] and the proof (for the upper bound) is simpler than that of the result in theorem I. But in basic sets of polynomials whether algebraic or not. α is obviously $\geqslant 1$ so that the argument to show that $\alpha \geqslant 1$, which is the same as that in theorem II, does not erise. The fact that the equality signs in (32) may take place will be illustrated by an example.

The cases $\alpha = 1$ in (22) and (31) give the following:

Corollary : Let $A = [a_{ij}]$ be an algebraic row - finie matrix, having a reciprocal $B = [b_{ij}]$ in P_A, then each of the two equalities.

$$(33) \quad \overline{\lim_{i \to \infty}} \frac{\log \alpha(i)}{\log i} = 1 , \quad \overline{\lim_{i \to \infty}} \frac{\log \beta(i)}{\log i} = 1$$

implies the other.

Also each of the two equalities

$$(34) \quad \overline{\lim_{i \to \infty}} \frac{\alpha(i)}{i} = 1 , \quad \overline{\lim_{i \to \infty}} \frac{\beta(i)}{i} = 1$$

implies the other.

Example (1) Consider the matrix $A = [a_{ij}]$ defined by :

$$(i) \text{ when } i = 4r + 1 , \quad a_{ij} = 1 \text{ when } j = 4r + 1$$
$$= -1 \text{ when } j = h(r) + 2$$
$$= 0 \text{ otherwise,}$$

(ii) when $i = 4r + 2$, $a_{ij} = 1$ when $j = 4r + 2$
$= 1$ when $j = h(r) + 3$
$= o$ otherwise,

(iii) when $i = 4r + 3$, $a_{ij} = 1$ when $j = 4r + 3$
$= -1$ when $j = h(r) + 4$
$= o$ otherwise,

(iv) when $i = 4r + 4$, $a_{ij} = 1$ when $j = 4r + 4$
$= o$ otherwise.

where $h(r) = \frac{1}{2}(4r)^2$, and $r = o, 1, 2, 3, \ldots$

It can be be checked that A is algebraic of degree 4, and that its minimal equation is

$$(A - I)^4 = O^*$$

We also have

$$\overline{\lim_{i \to \infty}} \frac{\alpha(i)}{i^2} = \tfrac{1}{2}^*$$

Thus, in this example, $m = 4$, $\alpha = 2$ and $p = \frac{1}{2}$

The reciprocal matrix $B = [b_{ij}]$ is found to be defined by**

---

* A simple method to get this minimal equation is to consider the matrix $A - I = Q = [q_{ij}]$, as generated by polynomials $q_i^{(z)} = \Sigma q_{ij} z^j$, $i = 1, 2, 3 \ldots$, then to evaluate the polynomials $q_i^{(2)}(z), q_i^{(3)}(z)$ and $q_i^{(4)} z$, generating the matrices Q^2, Q^3 and Q^4 $q^{(r)}(z)$ is simply evaluated from $q_i^{(r)}(z) = \Sigma q_{ij} q_j^{(r-1)}(z)$, $r = 2, 3, 4$. We find that $q^{(4)}(z)$ is identically zero for $i = 1, 2, 3, \ldots$

**A simple method to obtain the reciprocal matrix $B = [b_{ij}]$ is to consider the matrix $A = [a_{ij}]$ as generated by polynomials $A_i(z) = \Sigma_{aij} z^j$ then to solve these for powers of z, i. e. to obtain $z^i = \Sigma b_{ij} A_j(z)$. $i = 1, 2, 3, \ldots$

(i) when $i = 4r + 1$, $b_{ij} = 1$ when $j = 4r + 1, \frac{1}{2}(4r)^2 + 2, \frac{1}{2}(8r^2)^2 + 3, \frac{1}{2}(32r^4)^2 + 4$; $b_{ij} = o$ otherwise,

(ii) when $i = 4r + 2$, $b_{ij} = 1$ when $j = 4r + 2, \frac{1}{2}(4r)^2 + 3, \frac{1}{2}(8r^2)^2 + 4$: $b_{ij} = o$. otherwise

(iii) when $i = 4r + 3$, $b_{ij} = 1$ when $j = 4r + 3, \frac{1}{2}(4r)^2 + 4$
$= o$ otherwise,

(iv) when $i = 4r + 4$, $b_{ij} = 1$ when $j = 4r + 4$
$= o$ otherwise,

$r = o, 1, 2, 3, \ldots$

Hence

$$\overline{\lim_{i \to \infty}} \frac{\beta(i)}{i^8} = \lim_{r \to \infty} \frac{\beta(4r+1)}{(4r+1)^8}$$

$$\lim_{r \to \infty} \frac{\frac{1}{2}(32r^4)^2 + 4}{(4r+1)^8}$$

$$= \left(\frac{1}{2}\right)^7,$$

which shows that the equality sign in (8) may take place.

Again in this example,

$$\overline{\lim_{i \to \infty}} \frac{\log \alpha(i)}{\log i} = 2 = 8^{\frac{1}{3}}$$

$$\overline{\lim_{i \to \infty}} \frac{\log \beta(i)}{\log i} = 8 = 2^3,$$

so that considering B as the reciprocal of A we see that the equality sign for the upper bound in (23) may take place and considering A as the reciprocal of B we also see that the equality sign for the lower bound may take place.

Further, considering example (1) but with $h(r) = 5(4r)$,

$r = o, 1, 2, 3, \ldots$ again A has the minimal equation $(A - I)^4 = O$, and we have

$$\overline{\lim_{\to \infty}} \frac{\alpha(i)}{} = 5.$$

Also, we find that the reciprocal matrix $B = [b_{ij}]$ is such that, when $i = 4r + 1$, $b_{ij} = 1$ for $j = 4r + 1, 5(4r) + 2, 5(20r) + 3$ and $5(100r) + 4$; $= 0$ otherwise. This gives

$$\overline{\lim_{i \to \infty}} \frac{\beta(i)}{} = 125 = 5^3$$

which illustrates the occurrence of the signs of equality in (32).

We note that the fact that when (22) or (31) is satisfied we must have $\alpha \geqslant 1$ cannot be stated with the lower limit in place of the upper limit. Thus considering the matrix A defined by :

$$\left.\begin{array}{l} a_{i,i^2} = 1, \; a_{ij} = 0, \; j \neq i^2 \\ a_{i^2,i} = 1, \; a_{i^2,j} = 0, \; j \neq i \end{array}\right\} \text{when } i \text{ is a prime number,}$$

$a_{ii} = 1$, $a_{ij} = 0$, $j \neq i$ when i is neither a prime number nor the square of a prime number, we see that A is algebraic of dergee 2 and has the minimal eqution $A^2 = I$ so that A^{-1} exists in P_A and $A^{-1} = A$, but

$$\underline{\lim_{i \to \infty}} \frac{\log \alpha(i)}{\log i} = \tfrac{1}{2},$$

$$\underline{\lim_{i \to \infty}} \frac{\alpha(i)}{i} = 0,$$

Conditions on $\alpha(i)$ other than those in (22) and (31) may not lead to similar results. Thus for example if

$$\overline{\lim_{i \to \infty}} \frac{\log \alpha (i)}{i} = \alpha, \ 0 < \alpha < \infty ,$$

and if

$$\overline{\lim_{i \to \infty}} \frac{\lig \beta (i)}{i} = \beta .$$

then β may be infinte.

This fact may be illustrated by the following example.

Example (2) : Consider the matrix $A = [a_{ij}]$ defined by :

(i) when $i = 3r + 1$, $a_{ij} = 1$ when $j = 3r + 1$

$= -1$ when $j = 3^{r+1} + 2$

$= 0$ otherwise,

(ii) when $i = 3r + 2$, $a_{ij} = 1$ when $j = 3r + 2$

$= -1$ when $j = 3^{r+1} + 3$

$= 0$ otherwise,

(iii) when $i = 3r + 3$, $a_{ij} = 1$ when $j = 3r + 3$

$= 0$ otherwise,

$r = 0, 1, 2, 3, \ldots$

It can be checked that A is algebraic of degree 3, and that its minimal equation is

$$(A - I)^3 = 0.$$

It can also be checked that the reciprocal matrix B is defined by

(i) when $i = 3r + 1$, $b_{ij} = 1$ when $j = 3r + 1, 3^{r+1} + 2, 3^{3r+1} + 3$

$= 0$ otherwise,

(ii) when $i = 3r + 2$, $b_{ij} = 1$ when $j = 3r + 2,\ 3^{r+1} + 3$

$= o$ otherwise,

(iii) when $i = 3r + 3$, $b_{ij} = 1$ when $j = 3r + 3$

$= o$ otherwise,

$r = o, 1, 2, 3, \ldots$

In this example we have

$$\overline{\lim_{i \to \infty}} \frac{\log \alpha (i)}{i} = \lim_{r \to \infty} \frac{(r+1) \log 3}{3r + 1} = \frac{\log 3}{3}$$

$$\overline{\lim_{i \to \infty}} \frac{\log \beta (i)}{i} = \lim_{r \to \infty} \frac{(3^r + 1) \log 3}{3r + 1} = \infty .$$

But we notice that

$$\overline{\lim_{i \to \infty}} \frac{\log \log \beta (i)}{i} = \frac{\log 3}{3} .$$

In fact this example and a treatment similar to that given in the proof of theorem I illustrate the following result.

Theorem IVa : Let $A = [\, a_{ij} \,]$ be an algebraic row finite matrix of degree m, having a reciprocal $B = [\, b_{ij} \,]$ in P_Λ, and let

$$\overline{\lim_{i \to \infty}} \frac{\log \alpha (i)}{i} = \alpha,\ o < \alpha < \infty . \tag{35}$$

Then

$$\overline{\lim_{i \to \infty}} \frac{\log^{(m-1)} \beta (i)}{i} \leqslant \alpha \tag{36}$$

where $\log^{(m-1)} \beta (i)$ means the $(m-1)$ th logarithm of $\beta (i)$; the sign of equality may take place.

It is clear that here α is not necessarily $\geqslant 1$,

Further results of this type are the following :

Theorem IVb : Let $A = [a_{ij}]$ be an algebraic row-finite matrix of degree m, having a reciprocal $B = [b_{ij}]$ in P_A, and let

$$(37) \quad \overline{\lim_{i \to \infty}} \frac{\log \alpha(i)}{i \log i} = \alpha, \quad 0 < \alpha < \infty$$

Then

$$(38) \quad \overline{\lim_{i \to \infty}} \frac{\log^{(m-1)} \beta(i)}{i \log i} \leqslant \alpha;$$

the sign of equality may take place .

Theorem IVc : Let $A = [a_{ij}]$ be an algebraic row-finite matrix of degree m, having a reciprocal $B = [b_{ij}]$ in P_A, and let

$$(39) \quad \overline{\lim_{i \to \infty}} \frac{\log \log \alpha(i)}{\log i} = \alpha, \quad 0 < \alpha < \infty .$$

Then

$$(40) \quad \overline{\lim_{i \to \infty}} \frac{\log^{(m)} \beta(i)}{\log i} \leqslant \alpha ;$$

the sign of equality may take place .

It is clear that if in (35) , (37) and (39) , $\alpha > 1$, then the order of magnitude of $\alpha(i)$ increases with theorems IVa, IVb and IVc.

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ON THE RECIPROCAL MATRIX OF AN ALGEBRAIC ROW - FINITE MATRIX. II

By

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In paper I we have studied the order of magnitude of the function β (i) associated with the reciprocal matrix $B = [\, b_{ij} \,]$ when we are given the order of magnitude of the function α (i) associated with the algebraic row-finite matrix $A = [\, a_{ij} \,]$. In this paper we study the order of magnitude of the elements b_{ij} when we are given the order of ma nitude of the elements a_{ij}. We shall see that in the results given, the order of magnitude of the elements b_{ij} will depend on the order of magnitude of the function α (i) as well as on the order of magnitude of the elements a_{ij}.

We first state the following four results where we write,

(1) $$\max_j \left| a_{ij} \right| = \left| a_{i,s(i)} \right| , \quad i \geqslant 1 ,$$

(2) $$\max_j \left| b_{ij} \right| = \left| b_{i.t(i)} \right| , \quad i \geqslant 1 .$$

Theorem I : Let $A = [\, a_{ij} \,]$ be an algebraic row-finite matrix of degree m, having a reciprocal $B = [\, b_{ij} \,]$ in P_A. Also let,

(i) $$\overline{\lim_{i \to \infty}} \frac{\log \left| a_{i,s(i)} \right|}{i^u} = a , \quad o < u < \infty , \quad o < a < \infty ,$$

(ii) $$\overline{\lim_{i \to \infty}} \frac{\alpha(i)}{i} = \alpha , \quad 1 \leqslant \alpha < \infty .$$

Then

(iii) $$\overline{\lim_{i \to \infty}} \frac{\log \left| b_{i.t(i)} \right|}{i^u} \leqslant a \left(1 + \alpha^u + \alpha^{2u} + \ldots + \alpha^{\overline{m-2}u}\right) ;$$

the sign of equality may take place.

Theorem II : Let $A = [a_{ij}]$ be an algebraic row-finite matrix of degree m, having a reciprocal $B = [b_{ij}]$ in P_A. Also let

$$\text{(i)} \quad \overline{\lim_{i \to \infty}} \frac{\log |a_{i.s(i)}|}{i^u} = a \ , \ o < u < \infty, \ o < a < \infty,$$

$$\text{(ii)} \quad \overline{\lim_{i \to \infty}} \frac{\alpha(i)}{i^\alpha} = p \ , \ 1 < \alpha < \infty, o < p < \infty.$$

Then

$$\text{(iii)} \quad \overline{\lim_{i \to \infty}} \frac{\log |b_{i.t(i)}|}{i^{\alpha^{m-2}u}} \leqslant a \ p(1+\alpha+\alpha^2+ \ldots + \alpha^{m-3}) \ u;$$

the sign of equality may take place.

Theorem III : Let $A = [a_{ij}]$ be an algebraic row-finite matrix of degree m, having a reciprocal $B = [b_{ij}]$ in P_A. Also, let

$$\text{(i)} \quad \overline{\lim_{i \to \infty}} \frac{\log |a_{i,s(i)}|}{i^u \log i^u} = a \ , \ o < u < \infty, \ o < a < \infty$$

$$\text{(ii)} \quad \overline{\lim_{i \to \infty}} \frac{\alpha(i)}{i} = \alpha \ , \ 1 \leqslant \alpha < \infty$$

Then

$$\text{(iii)} \quad \overline{\lim_{i \to \infty}} \frac{\log |b_{i,t(i)}|}{i^u \log i^u} \leqslant a \ (1+\alpha u+\alpha^{2u}+\ldots+\alpha^{\overline{m-2}u});$$

the sign of equality may take place.

Theorem IV : Let $A = [a_{ij}]$ be an algebraic row-finite matrix of degree m, having a reciprocal $B = [b_{ij}]$ in P_A. Also, let,

$$(i) \quad \overline{\lim_{i \to \infty}} \frac{\log \left| a_{i,s(i)} \right|}{i^u \log i^u} = a, \; o < u < \infty, \; o < a < \infty$$

$$(ii) \quad \overline{\lim_{i \to \infty}} \frac{\alpha(i)}{i^\alpha} = p, \; 1 < \alpha < \infty, \; o < p < \infty$$

Then

$$iii) \quad \overline{\lim_{i \to \infty}} \frac{\log \left| b_{i,t(i)} \right|}{i^{\alpha^{m-2}u} \log i^{\alpha^{m-2}u}} \leqslant a \; p \, (1+\alpha+\alpha^2+\alpha^{m-3}) \, u,$$

the sign of equality may take place.

As the proofs of these results run on somewhat similar lines it is sufficient to give in full the proof of theorem III, for example, and the outlines of the proofs of the other theorems.

As in paper I, we have

$$(3) \quad b_{ij} = b_o \delta_{ij} + b_1 a_{ij} + b_2 \overset{(2)}{a_{ij}} + \ldots + b_{m-1} \overset{(m-1)}{a_{ij}}$$

From (ii) of theorem III, if we take β any number greater than α, we can find i_1 such that.

$$(4) \quad \overset{(r)}{\alpha}(i) < \beta^{r} i \text{ for all } i \geqslant i_1,$$

and where $r = 1, 2, 3, \ldots, m-1$.

From (i), if we take $b = a' u$, where a' is any number greater thad a, we can find i_2 such that.

$$\left| a_{ij} \right| < i^{b i^u} \text{ for all } i \geqslant i_2 \text{ and all } j.$$

We take K some constant $\geqslant 1$ such that

(5) $\left| a_{ij} \right| < Ki^{bi^u}$ for all $i \geqslant 1$ and all j.

It follows that

$$\left| \overset{(2)}{a_{ij}} \right| \leqslant \sum_{k=1}^{\alpha(i)} \left| a_{ik} \right| \left| a_{kj} \right|$$

$$< \beta i \,.\, Ki^{b\, i^u} \cdot K(\beta i)^{b\,(\beta i)^u}$$

$$= K^2(\beta i)\ \beta^b \beta^u i^u\ i^b\,(1+\beta^u) i^u \quad , \text{ for all } i \geqslant i_1 .$$

Consequently ;

$$\left| \overset{(3)}{a_{ij}} \right| \leqslant \sum_{k=1}^{\alpha(i)} \left| \overset{(2)}{a_{ik}} \right| \left| a_{kj} \right|$$

$$< (\beta^2 i) \,.\, K^2(\beta i)\, \beta^b \beta^u i^u i^b\,(1+\beta^u) i^u . K(\beta^2 i)^{b\,(\beta^2 i)^u}$$

$$= K^3\ (\beta i)\ (\beta^2 i)\ \beta^b\,(\beta^u + 2\beta^{2u})\ i^u\ i^b\,(1+\beta^u+\beta^{2u})\ i^u .$$

Proceeding in this way, we find that

(6) $\left| \overset{(r)}{a_{ij}} \right| < K^r\,(\beta i)\ (\beta^2 i)\ \ldots (\beta^{r-1} i)\beta^b\,(\beta^u + 2\beta^{2u} + \ldots + \overline{r-1}\beta^{\overline{r-1}u})\ i^u$

$Xi^b\,(1+\beta^u+\beta^{2u}+\ldots+\beta^{\overline{r-1}u})\, i^u$ for all $i < i_1$

Applying (3) and (6) we see that the dominant factor in $\left| b_{ij} \right|$ is

$$i^b\,(1+\beta^u+\beta^{2u}+\ \ldots\ldots + \beta^{\overline{m-2}\,u})\ i^u$$

for all $i \geqslant i_1$ and all j.

It follows that

$$\overline{\lim_{i \to \infty}} \frac{\log \left| b_i \,.\, t(i) \right|}{iu \log i} \leqslant b(1+\beta^u + \beta^{2u} + \ldots\ldots + \beta^{\overline{m-2}\,u}).$$

Noting that $b = a' u$ and that a' and β are arbitrary chosen greater than a and α respectively we have the required result in (i i i) of theorem III.

For the proof of theorem IV we note that when p' is any number greater than p, we can find i_1 such that *

$$(7) \quad \overset{(r)}{\alpha}(i) < p'^{\,1+\alpha+\alpha^2+\ldots+\alpha^{r-1}}\, i^{\alpha^r} \quad \text{for all } i \geqslant i_1.$$

Proceeding as in the proof of theorem III, we find that

$$\left| \overset{(2)}{a_{ij}} \right| < K^2 (p'^{\,i\alpha})\,(i^{\,bi^u})\,(p'^{\,i\alpha})^{\,b}\,(p'^{\,i\alpha})^{\,u},$$

$$\left| \overset{(3)}{a_{ij}} \right| < K^3 (p'^{\,i\alpha})\,(i^{\,bi^u})\,(p'^{\,i\alpha})^{\,b}\,(p'^{\,i\alpha})^{\,u}$$

$$X\,(p'^{\,1+\alpha}\, i^{\alpha})\,(p'^{\,1+\alpha}\, i^{\alpha^2})^{\,b}\,(p'^{\,1+\alpha}\, i^{\alpha^2})^{\,u}$$

and in general

$$\left| \overset{(r)}{a_{ij}} \right| < K^r (p'^{\,i\alpha})\,(i^{bi^u})\,(p'^{\,i\alpha})^{b}\,(p'^{\,i\alpha})^{u}$$

$$X\,(p'^{\,1+\alpha}\, i^{\alpha^2})\,(p'^{\,1+\alpha}\, i^{\alpha^2})^{\,b}\,(p'^{\,1+\alpha}\, i^{\alpha^2})^{u}$$

$$X \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots$$

$$X\,(p'^{\,1+\alpha+\ldots+\alpha^{r-2}}\, i^{\alpha^{r-1}})\,(p'^{\,1+\alpha+\ldots+\alpha^{r-2}}\, i^{\alpha^{r-1}})$$

$$b\,(p'^{\,1+\alpha+\ldots+\alpha^{r-2}}\, i^{\alpha^{r-1}})^{\,u}$$

Hence the dominant factor in $\left| b_{ij} \right|$ is

$$i^{\alpha^{m-2}}\, b^{p(1+\alpha+\alpha^2+\ldots+\alpha^{m-3})^{u}}\, i^{\alpha^{m-2}\,u}$$

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* See (19) of paper 1.

from which we get the required result in (i i i) of theorem IV.

In case of theorem I, taking b any number greater than a, we find a number $K \geqslant 1$ such that

$$(8) \qquad \left| a_{ij} \right| \geqslant K e^{bi^u} \qquad \text{for all } i \geqslant 1 \text{ and all } j,$$

and applying condition (i i) we get succeessively

$$\left| \overset{(2)}{a_{ij}} \right| < K^2 (\beta i)\, e^b (1+\beta^u)\, i^u \quad , \text{ for all } i \geqslant i_1 \text{ and all } j,$$

$$\left| \overset{(3)}{a_{ij}} \right| < K^3 (\beta i)(\beta^2 i)\, e^b (1+\beta^u+\beta^{2u})\, i^u,$$

$$\left| \overset{(r)}{a_{jj}} \right| < K^r (\beta i)(\beta^2 i) \ldots (\beta^{r-1} i)\, e^b (1+\beta u+\beta^2 u+ \ldots + (\beta^{r-1} u)\, i^u,$$

$r = 1, 2, \ldots m-1$; and this gives at once the required result in (iii) of theorem I.

In case of theorem II, we find in virtue of (7) and (8), that for $r = 1, 2, \ldots, m-1$

$$\left| \overset{(r)}{a_{ij}} \right| < K^r (p' i^\alpha)(p'^{1+\alpha} i^{\alpha^2}) \ldots (p'^{1+\alpha+\ldots+\alpha^{r-2}} i^{\alpha^{r-1}})$$

$$\times\, e^{bi^u} e^b (p' i^\alpha)^u e^b (p'^{1+\alpha} i^{\alpha^2})^u \times \ldots$$

$$\times\, e^b (p'^{1+\alpha+\ldots+\alpha^{r-2}} i^{\alpha^{r-1}})^u$$

for all $i \geqslant i_1$ and all j ;

so that the dominant factor in $\left| b_{ij} \right|$ is

$$ebp' \; (1 + \alpha + \alpha^2 + \; .... + \alpha^{m-3})^u \; {}_i\alpha^{m-2}{}_u$$

which gives at once the required result in (iii) of theorem II.

We note that in the above theorems it is assumed that $m \geqslant 3$, for when $m = 2$ we have the trivial case $B = b_0 I + b_1 A$ in which the order of growth of the elements b_{ij} is the same as that of the elements a_{ij}. when $m=1$ A is a scalar matrix and B is the reciprocal scalar matrix.

The fact that the sign of equality may take place in all cases may be illustrated as follows.

Example (1) : Consider the algebraic row-finite matrix $A = [a_{ij}]$ of degree 4 defind by :

(i) when $i = 4r + 1$, $a_{ij} = 1$ when $j = 4r + 1$

$= -F(r)$ when $j = h(r) + 2$

$= o$ otherwise.

(ii) when $i = 4r + 2$, $a_{ij} = 1$ when $j = 4(r) + 2$

$= -F(r)$ when $j = h(r) + 3$

$= o$ otherwise,

(iii) when $i = 4r + 3$, $a_{ij} = 1$ when $j = 4r + 3$

$= -F(r)$ when $j = h(r) + 4$

$= 0$ otherwise,

(iv) when $i = 4r + 4$, $a_{ij} = 1$ when $j = 4r + 4$

$= 0$ otherwise.

where

$F(r) = e^{a(4r)^u}$, $0 < a < \infty$, $0 < u < \infty$

$h(r) = \alpha(4r)$, α being an integer $\geqslant 1$,

$r = 0, 1, 2, ...$

This example satisfies the conditons of theorem I and it can be verified that

$$b_{4r+1,\alpha^3.4r+4} = e^{a(4r)^u} \cdot e^{a(\alpha.4r)^u} \cdot e^{a(\alpha^2.4r)^u}$$

$$= e^{a(1+\alpha^u+\alpha^{2u})(4r)^u}$$

which shows at once that

$$\overline{\lim_{i \to \infty}} \frac{\log | b_{i,t}(i)}{i^u} = a(1+\alpha^u+\alpha^{2u})$$

If in the above example, we take

$$F(r) = e^{a(4r)^u}, \quad 0 < a < \infty, \quad 0 < u < \infty$$

$$h(r) = \tfrac{1}{2}(4r)^{\alpha}, \quad \alpha \text{ being an integer} > 1,$$

we can verify that

$$b_{4r+1,(\frac{1}{2})^{1+\alpha+\alpha^2}(4r)^{\alpha^3}} = e^{a(4r)^u} \times e^{a(\frac{1}{2})^u(4r)^{\alpha u}}$$

$$\times e^{a(\frac{1}{2})^u(\frac{1}{2})^{\alpha u}(4r)^{\alpha^2 u}}$$

so that

$$\overline{\lim_{i \to \infty}} \frac{\log | b_{i,t}(i)|}{i^{\alpha^2 u}} = a(\tfrac{1}{2})^{(1+\alpha)u}$$

which shows that the upper bound in (iii) of theorem II is attainable.

Also if we take

$$F(r)^* = (4r)^{a(4r)^u}, \quad 0 < a < \infty, \quad 0 < u < \infty$$

$$h(r) = \alpha(4r) \qquad \alpha \text{ being an integer} \geqslant 1,$$

we verify that the upper bound in (iii) of theorem III is attainable.

Lastly, if we take

$$F(r) = (4r)^{a(4r)^u}, \quad 0 < a < \infty, \quad 0 < u < \infty$$

* When $r = 0$, we may take $F(r) = 1$

$h(r) = \frac{1}{2}(4r)^{\alpha}$, α being an integer $\geqslant 1$,

we verify that the upper bound in (iii) of theorem IV is attainable.

We note that the particular case $u = 1$ of theorem III forms the basic part of a fundamental theorem on algebraic basic sets of polynomials [1]. Also the particular cause $u = 1$ of theorem I may be grasped through the literature on algebraic basic sets [2].

We further notice that in each of the above theorems, the result in (iii), involves all the numbers introduced in (i) and (ii), and that there is some parallelism in the forms of (i) and (iii). In many other combinations of conditions (i) and (ii) we reach at a result (iii), not necessarily of the form (i) and not involving a number or more appearing in (i) or (ii). We do not give here any of snch results as we consider them non - interesting.

Another result in which the parallelism between the forms of (i) and (iii) is retained is as follows.

Theorem V : Let $A = [a_{ij}]$ be an algebraic row - finite matrix of degree m, having a reciprocal $B = [b_{ij}]$ in P_A. Also let

$$(i) \quad \overline{\lim_{i \to \infty}} \frac{\log \log |a_{i.s(i)}|}{\log i} = u \ , \ 0 < u < \infty$$

$$(ii) \quad \overline{\lim_{i \to \infty}} \frac{\log \alpha(i)}{\log i} = \alpha \ , \ 1 \leqslant \alpha < \infty$$

Then

$$(iii) \quad \frac{\log \log |b_{i.t(i)}|}{\log i} \leqslant \alpha^{m-2} u \ ,$$

the sign of equality may take place.

In this case, if we take v and β arbitrary greater than u and α respectively we have.

(9) $\left| a_{ij} \right| < k e^{i^v}$ for all $i \geqslant 1$ and all j,

(10) $\overset{(r)}{\alpha}(i) < i^{\beta^r}$ for all $i \geqslant i_1$,

comparing with (8) where now $b = 1$ and v is written for u. and applying (7) with $p' = 1$ and with β written for α, we get as in the proof of theorem II,

$$\left| \overset{(r)}{a}_{ij} \right| < k \quad i^{\beta + \beta^2 + \ldots + \beta^{r-1}} \quad e^{i^v} + i^{\beta v} + \ldots + i^{\beta^{r-1} v}.$$

Thus the dominant factor in $\left| b_{ij} \right|$ is $e^{i^{\beta^{m-2} v}}$, which gives the required result in (iii).

Also the upper bound in (iii) is attained in the example given to illustrate theorem II, where α is an integer > 1. It is also attained when $h(r) = (4r)^{\alpha}$, α being an integer $\geqslant 1$.

We must note that conditions (i) and (ii) of theorem V are "wider" than the corresponding conditions in theorem II, for in theorem V, we may have

$$\alpha(i) = i^{\alpha} \log i, \quad \left| a_{i, s(i)} \right| = e^{i^u} \log i$$

Thus the results in theorems II and V are independent.

When the elements a_{ij} are of small order of magnitude a treatment similar to the above one makes the number of non - zero elements in a row (which, in the i th row is $\leqslant \alpha(i)$ intervenes in the result. The construction of an algebraic matrix to illustrate the possibility of the upper bound in such a result is not easy making. In order to obtain " sharp " results which may be confirmed by exam-

ples we are lead to impose the further condition that the number of non-zero elements in a row is bounded. In fact, we have the following result in this direction.

Theorem VI . Let A be an algebraic row-finite matrix of degree m, having a reciprocal $B = [\, b_{ij} \,]$ in P_A . Also Let

$$\text{(i)} \quad \overline{\lim_{i \to \infty}} \frac{\log |a_{ij}|}{\log i} = a \,, \; o < a < \infty \,,$$

$$\text{(ii)} \quad \overline{\lim_{i \to \infty}} \frac{\log \alpha(i)}{\log i} = \alpha \,, \; 1 \leqslant \alpha < \infty \,,$$

(iii) the number of non-zero elements in a row be bounded.

Then

$$\overline{\lim_{i \to \infty}} \frac{\log |b_{ij}|}{\log i} \leqslant a \,(1 + \alpha + \alpha^2 + \ldots + \alpha^{m-2}) \,,$$

the sign of equality may take place.

In this case, we take b and β arbitrary greather than a and α respectively and then we have

$$\text{(11)} \quad |a_{ij}| < K i^{b} \quad \text{for all } i \geqslant 1 \text{ and all}$$

$$\text{(12)} \quad \alpha(i) < i^{\beta} \quad \text{for all } i \geqslant i_1 \,.$$

Also, if N_i is the number of non-zero elements in row$_i$, then there is a number N such that

$$\text{(13)} \quad N_i \leqslant N \quad \text{for all } i \geqslant 1 \,.$$

From (11), (12) and (13) we get successively

$$\left| \overset{(2)}{a_{ij}} \right| \leqslant \sum_k \left| a_{ik} \right| \left| a_{kj} \right|$$

$$< N\ K\ \ i^b\ \ K\ (i\beta)^b$$

$$= N\ K^2\ i^b\ (1+\beta)$$

$$\left| \overset{(3)}{a_{ij}} \right| \leqslant \sum_k \left| a_{ik} \right| \left| \overset{(2)}{a_{kj}} \right|$$

$$< N.\ Ki^b.\ NK^2(i\beta)^b\ (1+\beta)$$

$$= N^2K^3\ i^b\ (1+\beta+\beta^2)$$

In general

$$\left| \overset{(r)}{a_{ij}} \right| \leqslant \sum_k \left| a_{ik} \right| \left| \overset{(r-1)}{a_{kj}} \right|$$

$$< N^{r-1}\ K^r\ \ i^b(1+\beta+\beta^2 + \ldots + \beta^{r-1})$$

which gives the required result in (iv) .

The fact that the sign of equality in (iv) may take place is illustrated by example (1) when we take

$$F\ (r) = (4r)^a\ ,\quad 0 < a < \infty$$

$$h\ (r) = (4r)^\alpha\ ,\quad \alpha \text{ being an integer} \geqslant \quad .$$

In the above results we have been imposing in (i), conditions on the element a_{ij} which lead to inequalities such as (5), (8), (9) and (11), If we impose inequelities on a_{ij} similar to (5), (8), (9) or (11), but with a_{ij} in terms of j instead of i, then in virtue of condition (ii) on α (i) and the fact that in row i, $a_{ij} = o$ for all $j > \alpha$ (i) these inequalities involving j are converted into inequalities involvingi and again we may apply the above results. In fact, from the above six results we deduce respectively the following ones.

Cor. 1 : If in theorem I, condition (i) is replaced by

$$\text{(i)}' \quad \left| a_{ij} \right| \leqslant K e^{a j^{u}}, \quad o < a < \infty, \quad o < u < \infty,$$

then

$$\text{(ili)}' \quad \overline{\lim_{i \to \infty}} \frac{\log \left| b_{i,t(i)} \right|}{i^{u}} \leqslant a \left(\alpha^{u} + \alpha 2u + \dots + \alpha^{\overline{m-1}\, u} \right);$$

the sign of equality may take place.

Cor. 2 : If in theorem II, condition (i) is replaced by (i)' of cor. 1, then

$$\text{(iii)}' \quad \overline{\lim_{i \to}} \frac{\log \left| b_{i,t(i)} \right|}{i\, \alpha^{m-1} u} \leqslant a\, p \left(1 + \alpha + \alpha^{2} + \dots + \alpha^{m-2} \right) u,$$

the sign of equality may take place.

Cor. 3 : If in theorem III, condition (i) is replaced by

$$\text{(i)}' \quad \left| a_{ij} \right| \leqslant K\, j a j^{u}, \quad o < a < \infty, \quad o < u \leqslant \infty,$$

then :

$$\text{(iii)}' \quad \overline{\lim_{i \to \infty}} \frac{\log \left| b_{i,t(i)} \right|}{i^{u} \log i^{u}} \leqslant \frac{a}{u} \left(\alpha^{u} + \alpha^{2u} + \dots + \alpha^{\overline{m-1}u} \right);$$

the sign of equality may take place.

Cor. 4 : If in heorem IV, condition (i) is replaced by (i)' of cor. 3 then.

$$\text{(iii)}' \quad \overline{\lim_{i \to}} \frac{\log \left| b_{i,t(i)} \right|}{i \alpha^{m-1} u \log i \alpha^{m-1} u} \leqslant \frac{a}{u}\, p \left(1 + \alpha + \alpha^{2} + \dots + \alpha^{m-2} \right) u,$$

the sign of equality may take place.

Cor. 5 : If in theorem V, conditfon (i) is replaced by

$$(i)' \left| a_{ij} \right| \leqslant K\ e^{j^u}\ ,\ o < u < \infty ,$$

then

$$(iii)' \quad \overline{\lim_{i \to \infty}} \frac{\log \log \left| b_{i\,,\,t\,(i)} \right|}{\log i} \leqslant \alpha^{m-1} u\ ;$$

the sign of equality may take place.

Cor. 6 : If in theorem VI, condition (i) is replaced by.

$$(i)' \left| a_{ij} \right| \leqslant Kj^a\ ,\ o < a < \infty ,$$

then

$$(iv)' \quad \overline{\lim_{i \to \infty}} \frac{\log \left| b_{i\,,\,t\,(i)} \right|}{\log i} \leqslant a(\alpha + \alpha^2 + \ldots + \alpha^{m-1});$$

the sign of equality may take place.

In the case of cor. 1,we have.

$$(14) \left| a_{ij} \right| \leqslant K\ e^{aj^u} \leqslant K\, e^{a\,\{\alpha\,(i)\}^u} ,$$

so that in virtue of (ii) ,

$$\overline{\lim_{i \to \infty}} \frac{\log \left| a_{i\,,\,s\,(i)} \right|}{i^u} \leqslant \overline{\lim_{i \to \infty}}\ a \left\{ \frac{\alpha\ (i)}{i} \right\} = a\ \alpha^u$$

Comparing with (i) of theorem I, the argument of theorem I, shows that we have to write $a\,\alpha^u$ in place of a, in (iii). This gives the result in (iii) '.

In case of cor. 2, we have from (14) and (ii)

$$\overline{\lim_{i \to \infty}} \frac{\log \left| a_{i\,,\,s\,(i)} \right|}{i^{\alpha u}} \leqslant \overline{\lim_{i \to \infty}}\ a \left\{ \frac{\alpha\,(i)}{i^\alpha} \right\}^u = ap^u$$

Comparing with (i) of theorem II, the argument of theorem II, shows that we have to write αu in place of u and ap^u in place of a in (iii). This gives the required result in (iii)' of cor. 2.

In case of cor. 3, we have.

$$(15) \quad \left| a_{ij} \right| \leqslant K j^{a j^u} \leqslant K \{ \alpha (i) \}^{a \{ \alpha \ i) \}^u},$$

so that in virtue of (ii).

$$\overline{\lim_{i \to \infty}} \frac{\log \left| a_{i, s(i)} \right|}{i^u \log i} \leqslant \overline{\lim_{i \to \infty}} \left[a \left\{ \frac{\alpha (i)}{i} \right\} \frac{\log \alpha (i)}{\log i} \right] = a\alpha^u .$$

Thus we have to replace a by $\frac{a}{u} \alpha^u$ in (iii) of theorem III to get the result in (iii)' of cor. 3.

In case of cor. 4, we have from (15) and (ii)

$$\overline{\lim_{i \to \infty}} \frac{\log \left| a_{i, s(i)} \right|}{i^{\alpha u} \log i} \leqslant \overline{\lim_{i \to \infty}} \left[a \left\{ \frac{\alpha (i)}{i^\alpha} \right\} \frac{\log \alpha(i)}{\log i} \right] = a\alpha p^u .$$

Thus

$$\overline{\lim_{i \to \infty}} \frac{\log \left| a_{i, s(i)} \right|}{i^{\alpha u} \log i^{\alpha u}} \leqslant \frac{a}{u} p^u ,$$

so that we have to replace u by αu and a by $\frac{a}{u} p^u$ in (iii) of theorem IV to obtain the result in (iii)' of cor. 4.

It is also easily seen that we have to replace u by α u and a by αa in (iii) and (iv) of theorems V and VI respectively to get the results fn (iii)' and (iv)', of corollaries 5 and 6.

The fact that the up er bound is attainable in all cases may be illustrated by examples. For example the upper bound in cor. 1 is attained when we take example (1) with

$$F(r) = e^{a} \left\{ \alpha . 4r \right\}^{u}$$

$$h(r) = \alpha . 4r \text{ , } \alpha \text{ being an integer} \geqq 1 .$$

We have seen that when the conditions of theorem V are sharpened to the conditions of theorem II, the result obtained in theorem II is independent of that in theorem V. We now sharpen the conditions of theorem III to obtain a new result independent of theorem III.

Theorem VII : Let $A = [a_{ij}]$ be an algebraic row-finite matrix of degree m, having a reciprocal $B = [b_{ij}]$ in P_A. Also let

$$(1) \quad \overline{\lim_{i \to \infty}} \left\{ \left| a_{i,s(i)} \right| i^{-ai^{u}} \right\}^{1/i^{u}} = M \text{ , } 0 < u < \infty ,$$

$0 < a < \infty$, $0 < M < \infty$,

(ii) $\alpha(i) \leqslant \alpha i$ for all $i \geqslant i_1$, $1 \leqslant \alpha < \infty$.

Then

$$(iii) \quad \overline{\lim_{i \to \infty}} \left\{ \left| b_{i,t(i)} \right| i^{-a(1+\alpha^{u}+\alpha^{2u}+\ldots+\alpha^{\overline{m-2}u})} i^{u} \right\} \frac{1}{i^{u}}$$

$$\leqslant M^{1+\alpha^{u}+\alpha^{2u}+\ldots+\alpha^{\overline{m-2}u}} \alpha^{a(\alpha^{u}+2\alpha^{2u}+\ldots+\overline{m-2}\alpha^{\overline{m-2}u})} ;$$

the sing of equality may take place.

In virtue of (i), if we take M' auy number > M, we can find a number $K \geqslant 1$ such that

$$(16) \quad \left| a_{ij} \right| < K M'^{i^{u}} i^{ai^{u}} \quad \text{for all } i \geqslant 1.$$

Applying (16) and (ii) and proceeding as in the proof of theorem III we get

$$\left| a_{ij}^{(r)} \right| < (\alpha i)(\alpha^{2} i) \ldots (\alpha^{r-1} i) K^{r} M' (1+\alpha^{u}+\alpha^{2u}+\ldots+\alpha^{\overline{r-1}u}) i^{u}$$

$$\times \alpha^{a(\alpha^{u}+2a^{2u}+\ldots+\overline{r-1}\alpha^{\overline{r-1}u})} i^{u}$$

$$\times i^{a(1+\alpha^{u}+\alpha^{2u}+\ldots+\alpha^{\overline{r-1}u})} i^{u}$$

This together with (3) and the fact that $i^{1/i^u} \longrightarrow 1$ as $i \longrightarrow \infty$ gives the required result in (iii).

The fact that the sign of equality may take place is illustrated by example (1) when we take

$$F(r) = M^{(4r)^u} (4r)^{a(4r)^u}$$

$$h(r) = \alpha.4r \text{ , } \alpha \text{ being an integer} \geqslant 1.$$

The result corresponding to the particular case $u = 1$ may be grasped through the literature on algebraic basic sets of polynomials [2]. But the result there is stated with the condition $\overline{\lim_{i \longrightarrow \infty}} \alpha(i)/i = \alpha^*$ in place of the condition $\alpha(i) \leqslant \alpha i$ for all $i \geqslant i_1$. We give an example to show that this is definitely not the case and so in the associated results on algebraic basic sets of polynomials [2, theorems 1—A and 1—B] the condition $\overline{\lim_{i \longrightarrow \infty}} \alpha(i)^{**}/i = \alpha$. must be replaced by $\alpha(i) \leqslant \alpha i$ for all $i \geqslant i_1$).

Example (2) · Consider the algebraic matrix of degree 3. $A = [a_{ij}]$ defined by :

(i) when $i = 3r+1$, $a_{ij} = 1$ when $j = 3r+1$

$= -F(r)$ when $j = h(r)+2$

$= 0$ otherwise,

(ii) when $i = 3r+2$, $a_{ij} = 1$ when $j = 3r+2$

$= -F(r)$ when $j = h(r)+3$

$= 0$ otherwise,

(iii) when $i = 3r+3$, $a_{ij} = 1$ when $j = 3r+3$

$= 0$ otherwise,

---

* Condition (3) on page 319 of [2] is its equivalent.

** its equivalent.

$r = 6,7,8,\ldots$

$$F(r) = (3r+1)^{3r+1}$$

$h(r)$ = the first integer divisible by 3 and greater than $(3r+1)+(3r+1)/\log\log(3r+1)$.

(iv) $a_{ii} = 1$, $a_{ij} = o$, $j \mp i, 1 \leqslant i \leqslant 18$.

With the notation of theorem VII, we have, in this example $u = 1$, $a = 1$ and $M = 1$. Also $\lim\limits_{i \to \infty} \dfrac{\alpha(i)}{i} = 1$, and m being equa to 3, we have to evaluate.

$$\left\{ \overline{\lim_{i \to \infty}} \left| b_{i,t(i)} \right| i^{-2i} \right\}^{\frac{1}{i}}$$

We can verify that when $i = 3r + 1$, $r = 6, 7, 8, \ldots$

$$b_{i,t(i)} > i^{i}(i + i/\log\log i)^{i + i/\log\log i}$$

$$\geqslant i^{2i + i/\log\log i}$$

so that

$$\left\{ b_{i,t(i)} i^{-2i} \right\}^{\frac{1}{i}} > i^{1/\log\log i} \longrightarrow \infty \text{ as } i \longrightarrow \infty .$$

Thus condition (ii) of theorem VII can by no means be replaced by the condition $\overline{\lim\limits_{i \to \infty}}\ \alpha(i)/i = \alpha, 1 \leqslant \alpha < \infty$,

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ON THE TERNARY ANALYSIS OF THE PLETHYSM OF S-FUNCTIONS

By

RAGY H. MAKAR AND M. A. SIMARY

1. Introduction

The work in this note is a continuation to that in reference [5] and so the notation and symbols will be the same.

In [5] formulae have been obtained which enable us to evaluate the coefficient of the S-function $\{nm-k-r, k, r\}$, $k \leqslant m$, in the analysis of $\{m\} \otimes \{v\}$; where (v) is any partition of n and n=5 or 6. Here we consider the case n=7. The case n=8 is found to be seriously complicated, but for small k such as $k \leqslant 8$ it can be simply treated numerically.

2. The coefficient of the S-function $\{7m-k-r, k, r,\}$ $k \leqslant m$, in the analysis of $\{m\} \otimes \{v\}$, where (v) is any partition of 7.

when (v) is a partition of 7, then

$$\text{(A)} \quad \{m\} \otimes \{v\} = \frac{1}{7!} \sum_{(\alpha)} N_\alpha \chi^v_\alpha \{m\}^{\alpha_1} (\{m\}^{(2)})^{\alpha_2} \cdots$$

where the summation extends over the 15 classes (α) of the symmetric group of degree 7. The coefficient of the S-function $\{\lambda\} = \{7m-k-r, k, r,\}$ $k, \leqslant m$ in the analysis of $\{m\} \otimes \{v\}$ is given by $D_\lambda \{m\} \otimes \{v\}$. The value of $D_\lambda \{m\} \otimes \{v\}$ may be obtained by finding the result of operating with D_λ on each separate term on the right hand side of (A) and then gathering the results, making use of the character

table of the symmetric group of degree 7. The result of operating with D_λ on the term $\{m\}^{\alpha_1}$ $(\{m\}^{(2)})^{\alpha_2}$ ... may be obtained by the use of Foulkes differential operators.

We first describe very briefly the main outlines in the procedure.

(I) $D_\lambda \{m\}^7$ is simply obtained by applying [1, th. 2].

(II) To obtain $D_\lambda \{m\}^5 \{m\}^{(2)}$ we first operate with $\{m\}^5$, in the reverse sense, on D_λ, and then operate with the resulting sum of operators on $\{m\}^{(2)}$. In the expansion of $\{m\}^5$ we require only S-functions $\{5m-u-v, u, v\}$, $o \leqslant v \leqslant u$, for which $u \leqslant k$ and $v \leqslant r$ and the coefficient of such an S-function is given by [1, th. 2] as $\frac{1}{12}(u-v+1)(u+2)(u+3)(v+1)(v+2)$. Four cases arise according as the parities of k and r. when k and r are both even, say k=2l and r=2s we find that

$$D_\lambda \{m\}^5 \{m\}^{(2)} = \sum_{q=o}^{s} \sum_{p=q}^{l} \frac{1}{12} (2p-2q+1)(2p+2)$$

$$(2p+3)(2q+1)(2q+2)$$

$$- \sum_{q=o}^{s-1} \sum_{p=q}^{s-1} \frac{1}{12} (2p-2q+1)(2p+3)$$

$$(2p+4)(2q+2)(2q+3).$$

The answer is found to be as given below.

(III) To obtain $D_\lambda \{m\}^4 \{m\}^{(3)}$ we first operate with $\{m\}^4$ on D_λ and then operate with the resulting sum of operators on $\{m\}^{(3)}$. In the expansion of $\{m\}^4$ we require only S-functions $\{4m-u-v, u, v\}$, $o \leqslant v \leqslant u$, for which $u \leqslant k$ and $v \leqslant r$, and the coefficient of such an S-function is given again by [1, th. 2] as $\frac{1}{2}(u-v+1)(u+2)(v+1)$. Nine cases arise according as k, r = o, 1 or 2 (mod 3). When k = 3l and r = 3s, e.g., we find that

$$D_\lambda \{m\}^4 \{m\}^{(3)} = \sum_{q=o}^{s} \sum_{p=q}^{l} \tfrac{1}{2} (3p-3q+1)(3p+2)(3q+1)$$

$$- \sum_{q=0}^{s-1} \sum_{p=q}^{s-1} \tfrac{1}{2} (3p-3q+2)(3p+4)(3q+2).$$

The answer is found to be as given below.

(IV) To obtain $D_\lambda \{m\}^3 (\{m\}^{(2)})^2$ we first operate on D_λ with $\{m\}^3 = \sum_{u,v} (u-v+1) \{3m-u-v,u,v\}$ and then operate with the resulting sum of operators on $(\{m\}^{(2)})^2$. Four cases arise according as the parities of k and r. Making use of the equality [5,p.83], $D_{2m-l-s} D_l D_s \{m\}^2 = (l+1)(s+1)$, we find when $k=2l$ and $r=2s$ that

$$D_\lambda \{m\}^3 (\{m\}^{(2)})^2 = \sum_{q=o}^{s} \sum_{p=q}^{l} (2p-2q+1)(l-p+1)(s-q+1)$$

$$- \sum_{q=o}^{s-1} \sum_{p=q}^{s-1} (2p-2q+1)(l-q+1)(s-p)$$

The answer is found to be as given below.

(V) To obtain $D_\lambda \{m\}^3 \{m\}^{(4)}$ we first operate with $\{m\}^3$ on D_λ and then operate with the resulting sum of operators on $\{m\}^{(4)}$. Sixteen cases arise according as $k,r=0,1,2,$ or $3 \pmod 4$. When $k=4l$ and $r=4s$, e.g., we find that

$$D_\lambda \{m\}^3 \{m\}^{(4)} = \sum_{q=o}^{s} \sum_{p=q}^{l} (4p-4q+1) - \sum_{q=o}^{s-1} \sum_{p=q}^{s-1} (4p-4q+3).$$

(VI) To obtain $D_\lambda \{m\}^2 \{m\}^{(2)} \{m\}^{(3)}$ we first operate with $\{m\}^2 \{m\}^{(2)}$ on D_λ and then operate with the resulting sum of operators on $\{m\}^{(3)}$. In the expansion of $\{m\}^2 \{m\}^{(2)}$ we require only S-functions $\{4m-u-v,u,v\}$, $o \leqslant v \leqslant u$, for which $u \leqslant k$ and $v \leqslant r$. the coefficient of such an S-function is given in [1, p. 575] as $\frac{1}{2}(u+2)$ when u and v are both even, $\frac{1}{2}(u-v+1)$ when u is odd and v is even, $-\frac{1}{2}(v+1)$ when u and v are both odd and zero when u is even and v is odd. Thirty six cases arise corresponding to k, r=o, I, 2, 3. 4, 5, (mod 6). When k=6l and r=6s, e. g. we find that $D_\lambda \{m\}^2 \{m\}^{(2)} \{m\}^{(3)} =$

$$\sum_{q=o}^{s} \sum_{p=q}^{l} (3p+1) + \sum_{q=o}^{s} \sum_{p=q}^{l-1} (3p-3q+2) - \sum_{q=o}^{s-1} \sum_{p=q}^{l-1} (3q+2)$$

$$- \sum_{q=o}^{s-2} \sum_{p=q+1}^{s-1} (3p+2) + \sum_{q=o}^{s-1} \sum_{p=q}^{s-1} (3q+1) - \sum_{q=o}^{s-1} \sum_{p=q}^{s-1} (3p-3q+1.)$$

The answer is found to be as given below.

(VII) To obtain $D_\lambda \{m\}^2 \{m\}^{(5)}$ we first operate with $\{m\}^2 = \sum_{r=o}^{m} \{2m-r,r\}$ and then operate with the result on $\{m\}^{(5)}$. Twenty five cases arise accordding as k, r=o, 1, 2,.3, or 4 (mod 5), all cases being quite simple and the results are as given below.

(VIII) To obtain $D_\lambda \{m\} (\{m\}^{(2)})^3$ we first operate with $\{m\} \{m\}^{(2)}$ on D_λ and then operate with the result on $(\{m\}^{(2)})^2$. The coefficient of the S-function $\{3m-u-v,u.v,\}$ $o \leqslant u \leqslant v \leqslant m$, in $\{m\} \{m\}^{(2)}$, is given in [1, th. 13, cor. 1] as 1 when u and v are both even, —1 when u and v are both odd and zero when u and v are of different parities. Four cases arise according as the parities of k and r, and making use of the equality $D_{2m-l-s} D_l D_s \{m\}^2 = (l+1)(s+l)$, we find when k=2 l and r=2s, that

$$D_\lambda \{ m \}(\{ m \}^{(2)})^3 = \sum_{q=o}^{s} \sum_{p=q}^{l} (l-p+1)(s-q+1)$$

$$+ \sum_{q=o}^{s-1} \sum_{p=q}^{s-1} (l-q+1)(s-p).$$

(IX) To obtain $D_\lambda \{ m \}\{ m \}^{(2)} \{ m \}^{(4)}$ we first operate with $\{m\}\{m\}^{(2)}$ on D_λ and then operate with the result on $\{ m \}^{(4)}$. Sixteen cases arise according as $k.r=0,1,2,$ or $3 \pmod 4$. All cases are simply treated and the results are found to be as given below.

(X) To obtain $D_\lambda \{ m \} (\{ m \}^{(3)})^2$ we first operate with $\{ m \}$ on D_λ and then operate with the result on $(\{ m\}^{(3)})^2$. Nine cases arise according as $k,r=0,1$ or $2 \pmod 3$. All cases are quite simple.

(XI) $D_\lambda \{m\}\{m\}^{(6)}$ is obtained by operating first with $\{m\}$ on D_λ and then operating with the result on $\{m\}^{(6)}$. The 36 cases arising are very simple.

(XII) To obtain $D_\lambda (\{ m \}^{(2)})^2 \{ m \}^{(3)}$ we first operate with $(\{ m \}^{(2)})^2$ on D_λ and then operate with the resulting sum of operators on $\{ m \}^{(3)}$. The coefficient of the S-function $\{4m-u-v,u,v\}$, $u \leqslant m$ in $(\{ m \}^{(2)})^2$ is given in [1, p. 576] as $\frac{1}{2}(u+2)$ when u and v are both even, $-\frac{1}{2}(u-v+1)$ when u is odd and v is even, $-\frac{1}{2}(v+1)$ when u and v are both odd, and zero when u is even and v is odd. Thirty six cases arise corresponding to $k,r=0,1,2,3,4,5, \pmod 6$. When $k=6l$ and $r=6s$, e.g., we find that $D_\lambda (\{ m \}^{(2)})^2\{ m \}^{(3)} =$

$$\sum_{q=o}^{s} \sum_{p=q}^{l} (3p+1) - \sum_{q=o}^{s} \sum_{p=q}^{l-1} (3p-3q+2) - \sum_{q=o}^{s-1} \sum_{p=q}^{l-1} (3q+2)$$

$$- \sum_{q=o}^{s-2} \sum_{p=q+1}^{s-1} (3p+2) + \sum_{q=o}^{s-1} \sum_{p=q}^{s-1} (3q+1)$$

$$+ \sum_{q=o}^{s-1} \sum_{p=q}^{s-1} (3p-3q+1).$$

The answer is found to be as given below.

(XIII) To obtain $D_\lambda \{m\}^{(2)} \{m\}^{(5)}$ we first operate with $\{m\}^{(2)} = \sum_{r=o}^{m} (-1)^r \{2m-r,r\}$ on D_λ and then operate with the result on $\{m\}^{(5)}$. There are 100 cases corresponding to $k,r=0.1,2, \ldots 9 \pmod{10}$. All cases are very simply treated.

(XIV) To obtain $D_\lambda (m)^{(3)} (m)^{(4)}$ we first operate with $(m)^{(3)}$ on D_λ and then operate with the result on $(m)^{(4)}$. In the expansion of $\{m\}^{(3)}$ we require only S-functions $(3m-u-v,u,v)$, $o \leqslant v \leqslant u$, for which $u \leqslant k$ and $v \leqslant r$. The coefficient of such an S-function is given by the table

v/u	0	1	2 (mod 3)
0	1	-1	0
1	0	1	-1
2 (mod3)	-1	0	1

There are 144 cases correspondig to $k,r=0,1,2, \ldots, 11 \pmod{12}$. The answers are found to be as given below.

(XV) $D_\lambda \{ m \}^{(7)}$ is directly obtained by operating with D_λ

on $\{m\}$ $(^7)$. The 49 cases arising are very simple.

It is seen that the deriviation of the formulae for the coefficient of $\{\lambda\}$ in the expansion of $\{m\}\alpha_1$ $(\{m\}(^2))\alpha_2$ . . . varies widely from simplicity to complexity with the class (α). The results obtained are as follows.

(i) $\underline{2880\ D_\lambda\ \{m\}^7}$

$$= (k-r+1)(k+2)(k+3)(k+4)(k+5)(r+1)(r+2)(r+3)(r+4).$$

(ii) $\underline{3456\ D_\lambda\ \{m\}^5\ \{m\}(^2)}$

(a) when k and r are both even

$$3k(r+2)\,[(r+4)(2r+3)(k+6)(k^2+6k+14) - r(r+2)(r+4)\,.$$

$$(2k^2+21k+70)\,] - 72(3r^4+20r^3+30r^2-20r-48).$$

(b) wken k is even and r is odd

$$(k+2)(k+4)(r+1)(r+3)\,[k(3k+14)(2r+7) - (2k+9)(r-1)(3r+11)]$$

(c) when k is odd and r ie even

$$(k+1)(r+2)(r+4)\,[(k-1)(k+5)(3k+13)(2r+3) - (k+5)(2k+9).$$

$$(3r^2-2r-12) + 4(k-1)(2r+3) - 6(3r+4)(r-2) + 24] - 72r(r+2)^2(r+4).$$

(d) When k and r are both odd

$$(k-1)(r+1)(r+3)\,[(k+1)(3k^2+32k-3)(2r+7) + 6(19k+43)(2r+7)$$

$$-(k+1)(2k+21)(r-1)(3r+11) - 72(r-1)(3r+11)]$$

$$-72(r+1)(7r^3+33r^2-13r-147)\,.$$

(iii) $216\ D_\lambda\ \{m\}^4\{m\}^{(3)}$

k \ r	o	1	2 (mod 3)
o	$(k+3)\ (r+3)\ [k(2k+9)\ (r+2) - (k+4).\ (2r^2+3r-6)]$	$2k\ (r+2)\ [(k-3)\ (k+6)\ (r+3) - (k+7)\ (r^2-2r-17)] - 12\ (r-1)\ (r+2)\ (2r+7)$	$2k\ (r+1)\ (r+4)\ [(k-3).\ (k+6) - (k+7)\ (r-5)] - 12\ (r+1)\ (r+4)\ (2r-1)$
1	$2\ (k+2)\ (k+5)\ (r+3).\ [(r+2)\ (k-r+1)+2]$	$2\ (k+5)\ (k+2)\ (r+2).\ [(k-1)\ (r+3) - (r^2+r-8)]$	$(k-1)\ (r+1)\ (r+4)\ [(k-4)\ (2k+13) - (k+8).\ (2r-13)] - 36\ (r-2)\ (r+1).\ (r+4)$
2 (mod 3)	$(k+1)\ (r+3)\ [(k-2).\ (2k+11)\ (r+2) - (k+6).\ (2r^2-3r-18)] - 12r\ (r+3)^2$	$(k+1)\ (r+2)\ [(k-2)\ (2k+11).\ (r+3) - (k+6)\ (2r^2-r-25)] - 12\ (r+2)\ (r^2+4r+1)$	$(k+1)\ (r+1)\ (r+4)\ [(k-2)\ (2k+11) - (k+6)\ (2r-7)] - 12\ (r+1)^2\ (r+4)$

(iv) $192\, D_\lambda \{m\}^3 \left(\{m\}^{(2)}\right)^2$

k / r	even	odd
even	$(k+2)\ (r+2)\ (r+4)\ [k\ (k-r+7) - 4\ (r-3)\ ]$	$(k+2)\ (r+1)\ (r+3)\ [k(k-r+5) - 4(r-1)\ ]$
odd	$(r+2)\ (r+4)\ [\ (k-1)\ (k+1)\ (k-r+9)$ $-8(k-1)\ (r-3) - 24\ (r-2)\ ]$	$(r+1)\ (r+3)\ [(k-1)\ (k+1)\ (k-r+7)$ $-8(k-1)\ (r-1) - 24r]$

(v) $32\, D_\lambda \{m\}^3 \{m\}^{(4)}$

k / r	o	1	2	3 (mod 4)
o	$(k+4)\ (k-r+2)\ (r+4)$	$(k+4)\ (k-r+1)\ (r+3)$	$(k+4)\ (k-r)\ (r+2)$	$(k+4)\ (k-r-1)\ (r+1)$
1	$(k+3)\ (k-r+3)\ (r+4)$	$(k+3)\ (k-r+2)\ (r+3)$	$(k+3)\ (k-r+1)\ (r+2)$	$(k+3)\ (k-r)\ (r+1)$
2	$(k+2)\ (k-r+4)\ (r+4)$	$(k+2)\ (k-r+3)\ (r+3)$	$(k+2)\ (k-r+2)\ (r+2)$	$(k+2)\ (k-r+1)\ (r+1)$
3 (mod 4)	$(k+5)\ (k-r+1)\ (r+4)$	$(k+5)\ (k-r)\ (r+3)$	$(k+5)\ (k-r-1)\ (r+2)$	$(k+5)\ (k-r-2)\ (r+1)$

(vi) $72\ D_{\lambda}\ \{m\}^2\ \{m\}^{(2)}\ \{m\}^{(3)}$

k / r	o		2 (mod 6)
o	$k[k(r+6)-(r^2-2r-36)] + 12(r+6)$	$k[k(r-1)-(r^2-2r+13)] + 12(r-1)$	$(r+4)[k(k-r+6)+12]$
1	$(k-1)[(k-1)(r+6) - (r^2-4r-48)] -6(r^2+2r-12)$	$(k-1)[(k-1)(r-1) - (r^2-4r+15)] - 6(r^2+2r+9)$	$(r+4)[(k-1)(k-r+7) - 6(r-2)]$
2	$(k-2)[(k-2)(r+6) - (r^2-6r-60)] - 6(r^2-24)$	$(k-2)[(k-2)(r-1) - (r^2-6r+17)] - 6(r^2+11)$	$(r+4)[(k-2)(k-r+8) - 6(r-4)]$
3	$(k-3)[(k-3)(r+6) - (r^2-8r-72)] - 6(r^2-2r-36)$	$(k-3)[(k-3)(r-1) - (r^2-8r+19)] - 6(r^2-2r+13)$	$(r+4)[(k-3)(k-r+9) - 6(r-6)]$
4	$(k-4)[(k-4)(r+6) - (r^2-10r-84)] - 6(r^2-4r-48)$	$(k-4)[(k-4)(r-1) - (r-7)(r-3)] - 6(r^2-4r+15)$	$(r+4)[(k-4)(k-r+10) - 6(r-8)]$

5 (mod 6)	$(k-5)[(k-5)(r+6) - (r^2-12r-96)] - 12(r-6)(r+5)$	$(k-5)[(k-5)(r-1) - (r^2-12r+23)] - 12(r^2-r+12)$	$(r+4)[(k-5)(k-r+11) - 12(r-5)]$

k / r	3	4	5 (mod 6)
0	$(r+3)[k(k-r+5)+12]$	$(r+2)[k(k-r+4)+12]$	$(r+1)[k(k-r+3)+12]$
1	$(r+3)[(k-1)(k-r+6) - 6(r-1)]$	$(r+2)[(k-1)(k-r+5) - 6r]$	$(r+1)[(k-1)(k-r+4) - 6(r+1)]$
2	$(r+3)[(k-2)(k-r+7) - 6(r-3)]$	$(r+2)[(k-2)(k-r+6) - 6(r-2)]$	$(r+1)[(k-2)(k-r+5) - 6(r-1)]$
3	$(r+3)[(k-3)(k-r+8) - 6(r-5)]$	$(r+2)[(k-3)(k-r+7) - 6(r-4)]$	$(r+1)[(k-3)(k-r+6) - 6(r-3)]$
4	$(r+3)[(k-4)(k-r+9) - 6(r-7)]$	$(r+2)[(k-4)(k-r+8) - 6(r-6)]$	$(r+1)[(k-4)(k-r+7) - 6(r-5)]$
5 (mod 6)	$(r+3)[(k-5)(k-r+10) - 12(r-4)]$	$(r+2)[(k-5)(k-r+9) - 12(r-3)]$	$(r+1)[(k-5)(k-r+8) - 12(r-2)]$

(vii) $5\, D_\lambda \{m\}\ 2\{m\}^{(5)}$

k / r	o	1	2	3	4 (mod 5)
0	k+5	0	0	0	0
1	k+4	0	0	0	0
2	k+3	0	0	0	0
3	k+2	0	0	0	0
4 (mod 5)	k-r+1	- (r+4)	- (r+3)	- (r+2)	- (r+1)

(viii) $64\, D_\lambda \{m\}\ (\{m\}^{(2)})^3$

k / r	even	odd
even	(k+2) (k+4) (r+2) (r+4)	0
odd	0	-(k+3) (k+5) (r+1) (r+3)

(ix) $16\, D_\lambda \{m\}\ \{m\}^{(2)}\{m\}^{(4)}$

k / r	o	1	2	3 (mod 4)
0	(k+4) (r+4)	0	(k+4) (r+2)	0
1	0	-(k+3) (r+3)	0	-(k+3) (r+1)
2	(k+2) (r+4)	0	(k+2)(r+2)	0
3 (mod4)	0	-(k+5) (r+3)	0	-(k+5) (r+1)

(X) $9\, D_\lambda \{m\}(\{m\}^{(3)})^2$

k / r	0	1	2 (mod3)
0	(k+3) (r+3)	0	0
1	0	0	0
2 (mod3)	0	- (k + 4) (r+2)	0

(Xi) $D_\lambda \{m\}\ \{m\}^{(6)}$

= 1 when k,r = o (mod6),
= -1 when k = 5 (mod6) and r = 1 (mod6),
= 0 in all other cases.

(Xii) $12\ D_\lambda(\{m\}^{(2)})^2\{m\}^{(3)}$

k / r	0	1	2 (mod6)
0	(k+2) (r+4) +4	—2(k-r+1)	(k+2)(r+4)
1	-2 (k+5)	—(k +5) (r+1)	0
2	(k+4) (r+4)	—2(k + 4)	(k+4) (r+4)
3	-2 (k+3)	— (k+3) (r+1)	0
4	(k+2) (r+4)	— 2 (k+2)	(k+2) (r+4)
5 (mod6)	-2(k-r+1)	—[2(k-5)+(r+3)(r+5)]	2(r+4)

k / r	3	4	5 (mod6)
0	2 (r+3)	(k+2) (r+2)	2 (r+1)
1	—(k+5) (r+3)	0	—(k+5) (r+1)
2	0	(k+4) (r+2)	0
3	-(k+3) (r+3)	0	—(k+3) (r+1)
4	0	(k+2) (r+2)	0
5 (mod6)	-(k+5) (r+3)	(k—r+1) (r—4) +12	—(k+5) (r+1)

(Xiii) $D_\lambda\{m\}^{(2)}\{m\}^{(5)}$

k / r	0	1	2	3	4	5	6	7	8	9(mod 10)
0	1	0	0	0	0	1	0	0	0	0
1	-1	0	0	0	0	-1	0	0	0	0
2	1	0	0	0	0	1	0	0	0	0
3	-1	0	0	0	0	-1	0	0	0	0
4	1	-1	1	-1	1	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0	0
(9mod 10)	0	-1	1	-1	1	-1	0	0	0	0

(xiv) $D\lambda\{m\}^{(3)}\{m\}^{(4)}$

k \ r	0	1	2	3	4	5	6	7	8	9	10	11 (mod 12)
0	1	0	—1	1	1	—1	0	1	0	0	0	0
1	—1	1	0	—1	0	1	—1	0	0	0	0	0
2	0	—1	1	0	—1	0	1	—1	0	0	0	0
3	1	—1	0	1	0	—1	1	0	0	0	0	0
4	0	1	—1	0	1	0	—1	1	0	0	0	0
5	—1	0	1	—1	—1	1	0	—1	0	0	0	0
6	1	—1	0	1	0	—1	1	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0	0
11 (mod12)	0	—1	1	0	—1	0	1	—1	0	0	0	0

(xv) $D\lambda\{m\}^{(7)}$

k \ r	0	1	2	3	4	5	6 (mod7)
0	1	0	—1	0	0	0	0
1	—1	1	0	0	0	0	0
2	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0
	0	0	0	0	0	0	0
6 (mod7)	0	—1	1	0	0	0	0

Applying the above results, formula (A) and making use of the character table of the symmetric group of degree 7[2] we find that the coefficients of the S- functions $\{7m - k - r, k, r\}$, $1^* \leqslant r \leqslant k \leqslant 8$ in the analysis of $\{m\} \otimes \{\nu\}$, where (ν) is any partition of 7, are as follows, the coefficients being independent of $m \geqslant k$.

The coefficients of the S- functions $\{7m - k, k\}$, for all possible k, have been obtained in [3].

(I) Coefficient of $\{7m-k-r,k,r\}$ in $\{m\} \otimes \{7\}$, $m \geqslant k$

k \ r	1	2	3	4	5	6	7	8
1	0							
2	0	1						
3	0	1	0					
4	1	3	2	4				
5	1	4	3	5	1			
6	3	8	9	14	11	14		
7	4	10	12	20	18	23	9	
8	7	17	22	36	39	52	41	40

(II) Coefficient of $\{7m-k-r,k,r\}$ in $\{m\} \otimes \{61\}$, $m \geqslant k$

k \ r	1	2	3	4	5	6	7	8
1	0							
2	1	1						
3	2	3	2					
4	4	7	8	8				
5	7	13	17	21	14			
6	12	23	33	46	46	39		
7	18	37	56	82	94	101	68	
8	27	57	91	139	174	209	199	149

(III) Coefficient of $\{7m-k-r,k,r\}$ in $\{m\} \otimes \{52\}$, $m \geqslant k$

k \ r	1	2	3	4	5	6	7	8
1	0							
2	1	2						
3	2	4	2					
4	5	11	12	14				
5	9	19	25	34	22			
6	16	36	53	78	80	71		
7	25	57	91	140	166	184	126	
8	40	93	155	247	319	394	383	294

(IV) Coefficient of $\{7m-k-r,k,r\}$ in $\{m\} \otimes \{51^2\}$, $m \geqslant k$

k \ r	1	2	3	4	5	6	7	8
1	1							
2	1	0						
3	3	3	5					
4	5	6	11	7				
5	10	16	28	31	31			
6	15	27	50	64	77	53		
7	26	50	93	132	175	178	148	
8	38	77	148	222	312	362	380	258

(V) Coefficient of $\{7m-k-r, k, r\}$ in $\{m\} \otimes \{43\}$, $m \geqslant k$

k / r	1	2	3	4	5	6	7	8
1	0							
2	0	1						
3	1	3	3					
4	3	7	9	9				
5	5	14	20	25	20			
6	10	26	42	60	66	58		
7	17	44	74	114	143	158	115	
8	27	71	125	200	272	336	335	254

(VI) Coefficient of $\{7m-k-r, k, r\}$ in $\{m\} \otimes \{421\}$, $m \geqslant k$

k / r	1	2	3	4	5	6	7	8
1	0							
2	1	1						
3	2	4	4					
4	5	11	16	16				
5	10	23	39	51	44			
6	19	45	80	118	138	113		
7	32	79	148	231	305	335	258	
8	53	132	254	414	523	718	743	553

(VII) Coefficient of $\{7m-k-r, k, r\}$ in $\{m\} \otimes \{41^3\}$, $m \geqslant k$

k / r	1	2	3	4	5	6	7	8
1	0							
2	0	0						
3	1	1	3					
4	2	3	7	5				
5	4	8	18	21	23			
6	8	16	37	50	65	50		
7	14	31	69	105	150	161	136	
8	22	53	118	188	283	345	371	266

(VIII) Coefficient of $\{7m-k-r, k, r\}$ in $\{m\} \otimes \{3^2 1\}$, $m \geqslant k$

k / r	1	2	3	4	5	6	7	8
1	0							
2	0	0						
3	1	2	3					
4	1	4	7	5				
5	4	11	20	25	26			
6	7	20	39	56	72	55		
7	14	39	76	119	166	179	147	
8	22	63	128	210	310	380	404	293

(IX) Coefficient of $\{7m-k-r,k,r\}$ in $\{m\} \otimes \{32^2\}$, $m \geqslant k$

k/r	1	2	3	4	5	6	7	8
1	0							
2	0	1						
3	0	1	0					
4	1	4	5	8				
5	2	8	12	21	16			
6	5	18	31	54	62	59		
7	9	30	57	102	135	158	115	
8	17	55	107	193	275	358	368	296

(X) Coefficient of $\{7m-k-r,k.r\}$ in $\{m\} \otimes \{321^2\}$, $m \geqslant k$

k/r	1	2	3	4	5	6	7	8
1	0							
2	0	0						
3	0	1	2					
4	1	3	7	7				
5	3	9	20	28	29			
6	6	19	43	68	89	73		
7	12	38	86	144	208	235	194	
8	22	67	153	267	406	516	559	419

(XI) Coefficient of $\{7m-k-r,k,r\}$ in $\{m\} \otimes \{31^4\}$, $m \geqslant k$

k/r	1	2	3	4	5	6	7	8
1	0							
2	0	0						
3	0	0	0					
4	0	1	2	3				
5	0	1	4	7	5			
6	1	5	12	22	27	29		
7	2	8	23	43	62	79	60	
8	5	18	46	87	133	184	196	160

(XII) Coefficient of $\{7m\ k-r,k,r\}$ in $\{m\} \otimes \{2^3 1\}$, $m \geqslant k$

k/r	1	2	3	4	5	6	7	8
1	0							
2	0	0						
3	0	0	0					
4	0	1	1	3				
5	0	2	4	8	7			
6	1	5	11	22	27	27		
7	2	10	22	45	63	77	60	
8	4	19	43	86	131	177	189	154

(XIII) Coefficient of $\{7m-k-r,k,r\}$ in $\{m\} \otimes \{2^2\ 1^3\}$, $m \geqslant k$

k / r	1	2	3	4	5	6	7	8
1	0							
2	0	0						
3	0	0	0					
4	0	0	1	1				
5	0	1	3	6	6			
6	0	2	7	14	20	18		
7	1	6	17	34	52	64	56	
8	2	11	32	65	105	144	163	125

(XIV) Coefficient of $\{7m-k-r,k,r\}$ in $\{m\} \otimes \{21^5\}$, $m \geqslant k$

k / r	1	2	3	4	5	6	7	8
1	0							
2	0	0						
3	0	0	0					
4	0	0	0	1				
5	0	0	0	1	0			
6	0	0	1	4	4	7		
7	0	1	3	9	12	20	15	
8	0	2	7	19	29	48	53	46

(XV) Coefficient of $\{7\ m-k-r,k,r\}$ in $\{m\} \otimes \{1^7\}$, $m \geqslant k$

k / r	1	2	3	4	5	6	7	8
1	0							
2	0	0						
3	0	0	0					
4	0	0	0	0				
5	0	0	0	0	0			
6	0	0	0	0	0	0		
7	0	0	0	1	1	2	3	
8	0	0	0	1	2	4	5	4

We remark that according to theorems 30, 33 and 36 of Foulkes [1] the coefficient of the S-function $\{ 7m-k-r,k,r \}$, $k \leqslant m$, in $\{m\} \otimes \{v\}$ is also the coefficient of some other S-functions in the complete analysis of $\{m\} \otimes \{v\}$ r $\{m\} \otimes \{\tilde{v}\}$, where $(\tilde{v})$ is the conjugate partition of (v).

3. The coefficient of the S-function $\{ 8m-k-r,k,r \}$; $k \leqslant m$, in the analysis of $\{m\} \otimes \{v\}$, where (v) is any partition of 8, and $m \leqslant 8$.

When (v) is a partition of 8, we have the formula

$$(B) \quad \{m\} \otimes \{v\} = \frac{1}{8!} \sum_{(\alpha)} N_\alpha \quad \chi^v_\alpha \quad \{m\}^{\alpha 1} \quad (\{m\}^{(2)})^{\alpha 2 \ldots}$$

where the summation extends over the 22 clasess (α) of the symmetric group of degree 8. The deriviation of the formulae for the coefficient of the S-function $\{ 8m-k-r,k,r \}$, $k \leqslant m$ in some of the terms of (B) is so complicated that it is more convenient to consider each numerical case separately. If we require all such S-functions in all terms of (B), this is quite sensible when m is a small number, such as $m \leqslant 8$. The evaluated expansions of the expressions $\{m\}^{\alpha 1} \quad (\{m\}^{(2)})^{\alpha 2 \ldots}$ of weight nm, $n<8$, together with the application of Foulkes differential operators make the evaluation of the expansions of the expressions $\{m\}^{\alpha 1} \quad (\{m\}^{(2)})^{\alpha 2} \ldots$ of weight 8 m quite simple. The application of formula (B) to the evaluated expansions of these expressions, and the use of the character table of the symmetric group of degree 8, then give all S-functions $\{ 8m\ k-r,k,r \}$ $k \leqslant m$ in the ternary analysis of $\{m\} \otimes \{v\}$ where (v) is any partition of 8, and where $m \leqslant 8$.

We describe very briefly the procedure for evaluating the required expansions of the terms in formula (B). Of the 22 classes of the symmetric group of degree 8, there are 15 classes each containing at least one unary cycle. These are the classes obtained by adding a unary

cycle to the classes of the symmetric group of degree 7. We consider first the 15 terms in formula (B) corresponding to these classes containing each at least one unary cycle .

Assume, for example, that we require to determine the coefficient of the S-function $\{8m-12,7,5\}$ in the expansion of $\{m\}^6 \{m\}^{(2)}$. We evaluate $D_{8m-12,7,5} \{m\}^5 \{m\}^{(2)} \cdot \{m\}$; thus we operate with the expansion of $\{m\}^5 \{m\}^{(2)}$ on $D_{8m-12,7,5}$ and then collect the coefficients of D_m in the result . The expansion of $\{m\}^5 \{m\}^{(2)}$ contains 45 S-functions $\{7m-u-v,u,v\}$, $o \leqslant v \leqslant u \leqslant 8$, and the coefficients of these S-functions have been obtained as an intervening step in § 2 . Of these 45 S-functions, we require in the case under consideration, only 33 ones, namely those for which $u \leqslant 7$ and $v \leqslant 5$. Operating with the S-function $\{7m-6,4,2\}$, e. g. , on $D_{8m-12,7,5}$ we get

$$D_{8m-12,7,5}\{7m-6,4,2\} = \begin{vmatrix} D_{m-6} & X & X \\ 0 & D_3 & D_6 \\ 0 & D_0 & D_3 \end{vmatrix}$$

so that

$$D_{8m-12,7,5}\{7m-6,4,2\}\{m\} = \begin{vmatrix} 1 & X & X \\ 0 & 1 & 1 \\ 0 & 1 & 1 \end{vmatrix}$$

$$= 0 .$$

But operating with the S-function $\{7m-9,6,3\}$ we get

$$D_{8m-12,7,5}\{7m-9,6,3\} = \begin{vmatrix} D_{m-3} & X & X \\ 0 & D_1 & X \\ 0 & 0 & D_2 \end{vmatrix}$$

so that

$$D_{8m-12,7,5} \quad \{7m-9,6,3\}\{m\} = 1 .$$

Multiplying such results by the coefficients of the appropriate S-functions, and adding, for the 33 S-functions referred to above we get the coefficient of the S-function $\{8m-12,7,5\}$ in $\{m\}^6 \{m\}^{(2)}$. In this manner we obtain the coefficient of each of the 36 S-functions $\{8m-k-r,k,r,\}$, $1 \leqslant r \leqslant k \leqslant 8$ in the expansion of $\{m\}^6 \{m\}^{(2)}$. In this manner also we obtain the coefficient of each of these 36 S-functions in the other 14 expressions $\{m\}^{\alpha_1} (\{m\}^{(2)})^{\alpha_2}$ . . . corresponding to the classes (α) containing each, at least one unary cycle .

Of the 22 classes (α) of the symmetric group of degree 8 there are 4 classes each of which does not contain unary cycles but contains at least one binary cycle. These classes are (2^4), $(2^2 4)$, (23^2) and (26) and these are obtained by adding a binary cycle to the classes (2^3), (24) (3^2) and (6) of the symmetric group of degree 6. We describe how the expansions of the terms in formula (B) corresponding to the classes (2^4), $(2^4 4)$, (23^2) and (26) are evaluated.

Assume, for example, that we require to determine the coefficient, again of the S-function $\{8m-12,7,5\}$ in the expansion of $(\{m\}^{(2)})^2 \{m\}^{(4)}$. We evaluate $D_{8m-12,7.5} \{m\}^{(2)} \{m\}^{(4)} . \{m\}^{(2)}$. Thus we operate with the expansion of $\{m\}^{(2)} \{m\}^{(4)}$ on $D_{8m-12,7.5}$ and then operate with the resulting sum of operators on $\{m\}^{(2)}$. The expansion of $\{m\}^{(2)} \{m\}^{(4)}$ consisiting of 45 S-functions $\{6m-u-v,u,v\}$, $o \leqslant v \leqslant u \leqslant 8$ can be easily evaluated by the formulae of [5, p. 91]. Of these 45 S-functieons, we require the 33 ones for which $u \leqslant 7$ and $v \leqslant 5$ to operate with on $D_{8m-12,7,5}$. Operating, for example, with the S-function $\{6m-6,4,2\}$ we get

$$D_{8m-12,7,5}\ \{6m-6,4,2\} = \begin{vmatrix} D_{2m-6} & X & X \\ 0 & D_3 & D_6 \\ 0 & D_0 & D_3 \end{vmatrix}$$

so that. by the remarks in § 2 of [5]

$$D_{8m-12,7,5}\ \{6m-6,4,2\}\{m\}^{(2)} = \begin{vmatrix} 1 & X & X \\ 0 & 0 & 1 \\ 0 & 1 & 0 \end{vmatrix}$$

$$= -1$$

But operating with $\{6m-9,6,3\}$, we get

$$D_{8m-12,7,5}\ \{6m-9,6,3\} = \begin{vmatrix} D_{2m-3} & X & X \\ 0 & D_1 & X \\ 0 & 0 & D_2 \end{vmatrix}$$

so that, again by the remarks in § 2 of [5]

$$D_{8m-12,7,5}\ \{6m-9,6,3\}\{m\}^{(2)} = 0.$$

Multiplying such results by the coefficients of the appropriate S-functions and adding, for the 33 S-functions in concern we get the coefficient of the S-function $\{8m-12,7,5\}$ in $(\{m\}^{(2)})^2\{m\}^{(4)}$. In this manner we obtain the coefficient of the 36 S-functions $\{8m-k-r,k,r\}$, $1 \leqslant r \leqslant k \leqslant 8$ in the expansion of $(\{m\}^{(2)})^2\{m\}^{(4)}$. In this manner also we obtain the coefficient of each of these 36 S-functions in the expansions of $(\{m\}^{(2)})^4$, $\{m\}^{(2)}(\{m\}^{(3)})^2$ and $\{m\}^{(2)}\{m\}^{(6)}$, making use of the expansions of $(\{m\}^{(2)})^3$, $(\{m\}^{(3)})^2$ and $\{m\}^{(6)}$ as evaluated by applying the associate formulae in [5].

Now remains the evaluation of the expansions of the expressions $\{m\}^{(3)}\{m\}^{(5)}$, $(\{m\}^{(4)})^2$ and $\{m\}^{(8)}$.

To obtain the coefficient of $\{\lambda\} = \{8m-k-r,k,r\}$, $k \leqslant m$, in the expansion of $\{m\}^{(3)} \{m\}^{(5)}$ we evaluate $D_\lambda \{m\}^{(3)} . \{m\}^{(5)}$ in the same way as we have evaluated $D_{7m-k-r,k,r} \{m\}^{(3)} . \{m\}^{(4)}$ in § 2. There are 225 cases corresponding to $k,r = 0, 1, 2, \ldots, 14$ (mod 15), but of these we have to evaluate only the 36 required ones.

To obtain the coefficient of $\{\lambda\} = \{8m-k-r,k.r\}$, $k \leqslant 8$, in the expansion of $(\{m\}^{(4)})^2$, we evaluate $D_\lambda (\{m\}^{(4)})^2$, by the method explained in § 2 of [5]. There are 16 cases corresponding to $k, r = 0,1,2,3$ (mod 4) and the results are

$$16\, D_\lambda \left(\{m\}^{(4)} \right)^2$$

K / r	0	1	2	3 (mod 4)
0	(k+4) (r+4)	0	-(k+4) (r+2)	0
1	-(k+3) (r+4)	(k+3) (r+3)	0	0
2	0	0	0	0
3(mod4)	0	-(k+5) (r+3)	(k+5) (r+2)	0

The coefficient of $\{8m-k-r.k.r\}$, $k \leqslant m$, in the expansion of $\{m\}^{(8)}$ is very easily, obtained by applying the remarks in § 2 of [5].

Applying formula (B), the evaluated expansions of the expressions on the right hand side of (B), and the character table of the symmetric group of degree 8 [2], give the following tables for the coefficient of the S-function $\{8m-k-r.k.r\}$, $1^* \leqslant r \leqslant k \leqslant 8$ in $\{m\} \otimes \{v\}$ where (v) is any partition of 8, these coefficients being independent of $m \geqslant k$.

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* The coefficients of the S-functions $\{8m-k,k\}$, $0 \leqslant k \leqslant 4m$, have been obtained in [4]

(I) Coefficient of $\{8m-k-r, k, r\}$ in $\{m\} \otimes \{8\}$, $m \geqslant k$

k / r	1	2	3	4	5	6	7	8
1	0							
2	0	1						
3	0	1	0					
4	1	3	2	4				
5	1	4	3	5	1			
6	3	8	9	15	12	16		
7	4	11	13	22	21	28	12	
8	7	18	24	41	46	64	53	52

(II) Coefficient of $\{8m-k-r, k, r\}$ in $\{m\} \otimes \{7^1\}$, $m \geqslant k$

k / r	1	2	3	4	5	6	7	8
1	0							
2	1	1						
3	2	3	2					
4	4	7	8	8				
5	7	13	17	22	15			
6	12	24	35	50	53	47		
7	19	39	61	93	112	126	88	
8	29	62	102	162	214	269	267	208

(III) Coefficient of $\{8m-k-r, k, r\}$ in $\{m\} \otimes \{6^2\}$, $m \geqslant k$

k / r	1	2	3	4	5	6	7	8
1	0							
2	1	2						
3	2	4	2					
4	5	11	12	15				
5	9	20	27	38	27			
6	17	39	59	92	99	92		
7	27	63	105	170	214	247	179	
8	44	107	185	313	427	554	567	459

(IV) Coefficient of $\{8m-k-r, k, r\}$ in $\{m\} \otimes \{6^{1^2}\}$, $m \geqslant k$

k / r	1	2	3	4	5	6	7	8
1	1							
2	1	0						
3	3	3	5					
4	5	6	11	7				
5	10	16	29	33	35			
6	16	28	54	72	92	67		
7	27	54	103	154	215	231	199	
8	41	85	171	270	402	492	542	392

(V) Coefficient of $\{8m - k - r, k, r\}$ in $\{m\} \otimes \{53\}$, $m \geqslant k$

k/r	1	2	3	4	5	6	7	8
1	0							
2	0	1						
3	1	3	3					
4	3	8	11	12				
5	6	17	26	36	29			
6	12	32	56	86	100	91		
7	21	58	104	173	228	268	208	
8	35	96	184	315	455	597	636	506

(VI) Coefficient of $\{8m - k - r, k, r\}$ in $\{m\} \otimes \{521\}$, $m \geqslant k$

k/r	1	2	3	4	5	6	7	8
1	0							
2	1	1						
3	2	4	4					
4	5	11	17	18				
5	11	25	44	62	57			
6	20	50	94	148	184	158		
7	36	92	183	306	430	499	412	
8	61	159	327	572	860	1127	1243	977

(VII) Coefficient of $\{8m-k-r, k, r\}$ in $\{m\} \otimes \{51^3\}$, $m \geqslant k$

k/r	1	2	3	4	5	6	7	8
1	0							
2	0	0						
3	1	1	3					
4	2	3	7	5				
5	4	8	19	23	27			
6	8	17	40	58	80	65		
7	15	33	79	127	195	222	199	
8	24	60	140	240	385	502	574	438

(VIII) Coefficient of $\{8m-k-r, k, r\}$ in $\{m\} \otimes \{4^2\}$, $m \geqslant k$

k/r	1	2	3	4	5	6	7	8
1	0							
2	0	0						
3	0	1	1					
4	1	3	5	6				
5	2	5	10	13	10			
6	4	13	23	37	42	42		
7	7	21	43	70	95	117	88	
8	13	39	77	137	196	267	283	233

(IX) Coefficient of $\{ 8\,m\text{-}k\text{-}r, k, r \}$ in $\{m\} \otimes \{ 431 \}$, $m \geqslant k$

k / r	1	2	3	4	5	6	7	8
1	0							
2	0	0						
3	1	2	4					
4	2	6	12	11				
5	5	16	33	46	47			
6	11	33	72	114	152	133		
7	22	66	145	249	369	437	375	
8	38	117	263	472	745	998	1127	890

(X) Coefficient of $\{ 8\,m\text{-}k\text{-}r, k, r \}$ in $\{m\} \otimes \{ 42^2 \}$, $m \geqslant k$

k / r	1	2	3	4	5	6	7	8
1	0							
2	0	1						
3	0	1	0					
4	1	5	6	11				
5	2	9	16	29	24			
6	6	23	43	82	101	104		
7	11	40	85	164	237	300	238	
8	22	79	168	331	511	720	797	679

(XI) Coefficient of $\{ 8m\text{-}k\text{-}r, k, r \}$ in $\{m\} \otimes \{ 421^2 \}$, $m \geqslant k$

k / r	1	2	3	4	5	6	7	8
1	0							
2	0	0						
3	0	1	2					
4	1	3	8	9				
5	3	10	24	37	41			
6	7	22	56	96	136	122		
7	14	48	118	218	339	417	369	
8	27	88	224	427	707	974	1135	916

(XII) Coefficient of $\{ 8m\text{-}k\text{-}r, k, r \}$ in $\{n\} \otimes \{ 41^4 \}$, $m \geqslant k$

k / r	1	2	3	4	5	6	7	8
1	0							
2	0	0						
3	0	0	0					
4	0	1	2	3				
5	0	1	4	8	6			
6	1	5	13	26	35	40		
7	2	9	27	55	87	119	99	
8	5	20	56	117	196	294	340	295

(XIII) Coefficient of $\{8m-k-r,k,r\}$ in $\{m\}\otimes\{3^2 2\}$. $m \geqslant k$

k / r	1	2	3	4	5	6	7	8
1	0							
2	0	0						
3	0	1	1					
4	0	1	3	3				
5	1	5	10	16	19			
6	2	10	24	42	62	56		
7	5	23	52	99	155	193	169	
8	10	40	99	193	323	448	522	424

(XIV) Coefficient of $\{8m-k-r,k,r\}$ in $\{m\}\otimes\{3^2 1^2\}$, $m \geqslant k$

k / r	1	2	3	4	5	6	7	8
1	0							
2	0	0						
3	0	0	1					
4	0	1	3	3				
5	1	3	11	16	21			
6	2	14	25	45	68	61		
7	5	19	56	104	175	216	199	
8	10	40	108	214	368	517	615	500

(XV) Coefficient of $(8m-k-r,k,r)$ in $\{m\}\otimes\{3^2 1\}$, $m \geqslant k$

k / r	1	2	3	4	5	6	7	8
1	0							
2	0	0						
3	0	0	0					
4	0	1	2	4				
5	0	3	7	16	16			
6	1	8	21	46	67	70		
7	3	18	48	106	172	229	200	
8	7	37	100	220	380	562	664	569

(XVI Coefficient of $\{8m-k-r,k,r\}$ in $\{m\}\otimes\{321^3\}$, $m \geqslant k$

k / r	1	2	3	4	5	6	7	8
1	0							
2	0	0						
3	0	0	0					
4	0	0	1	2				
5	0	1	4	8	11			
6	0	3	12	27	43	45		
7	1	8	29	67	117	160	150	
8	3	19	63	145	265	402	495	426

(XVII) Coefficient of $\{8m-k-r,k,r\}$ in

$\{m\} \otimes \{31^5\}$, $m \geqslant k$

k / r	1	2	3	4	5	6	7	8
1	0							
2	0	0						
3	0	0	0					
4	0	0	0	1				
5	0	0	0	1	0			
6	0	0	1	5	6	11		
7	0	1	3	12	18	34	28	
8	0	2	9	28	50	90	111	108

(XVIII) Coefficient of $\{8m-k-r,k.r\}$ in

$\{m\} \otimes \{2^4\}$, $m \geqslant k$

k / r	1	2	3	4	5	6	7	8
1	0							
2	0	0						
3	0	0	0					
4	0	0	0	1				
5	0	0	0	1	1			
6	0	1	2	6	8	12		
7	0	1	4	12	20	31	25	
8	0	4	10	29	50	83	96	93

(XIX) Coefficient of $\{8m-k-r,k,r\}$ in

$\{m\} \otimes \{2^3 1^2\}$, $m \geqslant k$

k /	1	2	3	4	5	6	7	8
1	0							
2	0	0						
3	0	0	0					
4	0	0	0	0				
5	0	0	1	2	4			
6	0	0	2	6	12	11		
7	0	2	7	19	37	52	54	
8	0	3	15	40	82	127	168	141

(XX) Coefficient of $\{8m-k-r, k, r\}$ in

$\{m\} \otimes \{2^2 1^4\}$, $m \geqslant k$

k / r	1	2	3	4	5	6	7	8
1	0							
2	0	0						
3	0	0	0					
4	0	0	0	0				
5	0	0	0	1	1			
6	0	0	0	2	4	5		
7	0	0	2	7	15	23	26	
8	0	1	5	18	37	65	89	80

(XXI) Coefficient of $\{8m-k-r, k, r\}$ in $\{m\} \otimes \{21^6\}$, $m \geqslant k$

$/^r$	1	2	3	4	5	6	7	8
1	0							
2	0	0						
3	0	0	0					
4	0	0	0	0				
5	0	0	0	0	0			
6	0	0	0	0	0	0		
7	0	0	0	1	2	4	6	
8	0	0	0	2	5	11	18	16

(XXII) Coefficient of $\{8m-k-r, k, r\}$ in $\{m\} \otimes \{1^8\}$, $m \geqslant k$

$k/^r$	1	2	3	4	5	6	7	8
1	0							
2	0	0						
3	0	0	0					
4	0	0	0	0				
5	0	0	0	0	0			
6	0	0	0	0	0	0		
7	0	0	0	0	0	0	1	
8	0	0	0	0	0	0	1	0

The coefficient of the S-function $\{8m-k-r, k, r\}$, $k \leqslant m$, in $\{m\} \otimes \{\upsilon\}$ is also the coefficient of some other S-functions in $\{m\} \otimes \{\upsilon\}$ or $\{m\}' \otimes \{\tilde{\upsilon}\}$.

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ON THE DEFINITE INTEGRAL SOLUTIONS OF THE DIFFERENTIAL EQUATION

$$y^{(k)} + xy = o$$

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In a previous paper [1], the definite integral solutions of the differential equation

$$y^{(k)} - xy = o, \qquad (I)$$

have been discussed through the familiar method used for such solutions. The fundamental idea which underlies this method is the assumption of the definite integral solution in the form

$$y = \int e^{xt} \varphi(t)\, dt$$

then the insertion of this integral in the differential equation under consideration in order to determine the form of the function φ (t) as well as the limits of integration. For the details of the solution the reader may be referred to [1].

Through this method a class of k distinct definite integral solutions has been obtained. This class is complete in itself in the sense that it does furnish a complete primitive.

Moreover, but not through this method, another class of definite integral solutions has been obtained. Sueh a class is by no means complete as the solutions obtained cannot make up a complete primitive.

In the present paper, it is found that a change in the assumed integral to the form

$$y = \int e^{\omega xt} \varphi(t) dt,$$

makes it possible to obtain in a systematic manner two complete classes of definite integral solutions of the differential equation

$$y^{(k)} + x\,y = o \qquad \text{(II)}$$

For the differential equation (I) , a discussion through the same considerations will be retained to a further note. It may be remarked that replacing x by $-x$ transforms (I) to (II) and vice versa only when k is even.

1. DESCRIPTION OF THE PROPOSED METHOD

To solve the differential equation

$$y^{(k)} + x\,y = o\,, \qquad (1)$$

assume that ,

$$y = \int e^{\omega x t}\,\Psi\,(t)\,dt,$$

where ω is in general a complex quantity and Ψ (t) is a function of the real variable t but not of x, the form of this function and the limits of integration (supposed independent of x) are to be determined by inserting the assumed integral in the differential equation. We thus have .

$$\omega^k \int t^k\, e^{\omega x t}\,\Psi\,(t)\,dt + x \int e^{\omega x t}\,\Psi\,(t)\,dt = o$$

Integrating by parts, the above identity becomes

$$\omega^k \int t^k\, e^{\omega x t}\,\psi\,(t)\,dt + \left[\frac{1}{\omega}\, e^{\omega x t}\Psi(t)\right] - \frac{1}{\omega}\int e^{\omega x t}\,\frac{d}{dt}\,\Psi(t)\,dt = o,$$

where the middle term is taken between the limits of integration as yet unknown.

The last equation will be satisfied if

$$\frac{d}{dt}\,\Psi\,(t) = \omega^{k+1}\,t^k\,\psi\,(t), \qquad (2)$$

for all values of t within the range of integration, and if

$$\left[\frac{1}{\omega}\, e^{\omega x t}\,\Psi\,(t)\right] = o, \qquad (3)$$

between the limits. Equation (2) determines Ψ (t) as a fnnction of t whilst (3) will determine the limits of the assumed iutegral. Equation (2) gives directly.

$$\Psi(t) = C \exp\left\{ \omega^{k+1} t^{k+1} / (k+1) \right\},$$

where C is an arbitrary constant. Then the equation determining the limits will take the form.

$$\left[\frac{C}{\omega} \exp\left\{ \omega x t + \omega^{k+1} t^{k+1} / (k+1) \right\} \right] = o$$

We may take 0 and ∞ as the limits of the definate integral so that the left hand side of the last equation reduces to—C/ω provided that

$$\left.\begin{array}{l} \text{(i) } RI\ \omega^{k+1} < 0, \\ \text{or} \\ \text{(ii) } RI\ \omega^{k+1} = 0, \text{ and } x\ RI\ \omega < 0. \end{array}\right\} \qquad (4)$$

Writing

$$F_k(x;\omega) = \int_0^\infty \exp\left\{ \omega x t + \omega^{k+1} t^{k+1} / (k+1) \right\} dt \qquad (5)$$

we readily see that the definite integral $C_\omega F_k(x, \omega)$ is a particular integral of the differential equation

$$y^{(k)} + x y = C$$

where ω satisfies any of the conditions (4.i) or (4.ii).

It will be seen that associated with (4.i) or (4.ii), there corresponds a complete class of definite integral solutions.

2. THE FIRST CLASS OF DEFINITE INTEGRAL SOLUTIONS

This class is characterized by the choice of a complex number ω for which Rl $\omega^{k+1} < 0$. For the sake of simplicity of the form of the solution, we take

$$\omega^{k+1} = -1$$

However, the form of the primitive will differ according as k is even or odd, for this reason we consider each case seperately.

CASE I. $k = 2n$.

In this case, the differential equation is

$$y^{(2n)} + xy = o, \tag{6}$$

and the corresponding values of ω are given by $\omega^{2n+1} = -1$, so that.

$$\omega = -1, e^{\pm i\theta_r},$$

where

$$\theta_r = \frac{2r+1}{2n+1}\pi, \quad r = o, 1, \ldots, n-1$$

It may be remarked that $e^{i\theta_n} = e^{-i\theta_n} = -1$. Then with the notation introduced in (5), we see that.

$$y = \sum_{r=o}^{n} C_r e^{i\theta_r} F_{2n}\left(x; e^{i\theta_r}\right)$$

where $C_o, C_1, \ldots, C_n$ are arbitrary constants, is a solution provided that

$$\sum_{r=o}^{n} C_r = o$$

Remembering that $e^{i\theta_n} = -1$ and substituting for C_n its value as given by (8), then (7) will take the form

$$y = \sum_{r=o}^{n-1} C_r e^{i\theta_r} \left\{ F_{2n}(x; e^{i\theta_r}) + e^{-i\theta_r} F_{2n}(x; -1) \right\}$$

It is readily seen that

$$G_{2n}(x; e^{i\theta_r}) = F_{2n}(x; e^{i\theta_r}) + e^{-i\theta_r} F_{2n}(x; -1):$$

$$r = o, 1, \ldots, n-1 \tag{9}$$

form n distinct solutions of the differential equation (6). In a similar way

$G_{2n}(x; e^{-i\theta r} : r = o, 1, \ldots, n-1$

form other n distinct solutions, which when combined together with

$G_{2n}(x; e^{i\theta_r})$ make up a complete primitive.

Furthermore, it is evident that the real and imaginary parts of $G_{2n}(x; e^{i\theta_r})$ which we denote by $Ci_{2n}(x; \theta_r)$ and $Si_{2n}(x; \theta_r)$ respectively are

distinct solutions of (6). Writing

$$G_{2n}(x; e^{i\theta r}) = Ci_{2n}(x; \theta r) + i\, Si_{2n}(x; \theta r)$$

we see on using (9) and (5) that

$$Ci_{2n}(x; \theta r) = \int_0^\infty \left\{ \exp\left(xt\cos\theta_r - \frac{t^{2n+1}}{2n+1}\right) \right\} \cos(xt\sin\theta_r)\, dt$$

$$+ \cos\theta_r \int_0^\infty \exp\left(-xt - t\frac{2n+1}{2n+1}\right) dt, \tag{10}$$

$$Si_{2n}(x;\theta_r) = \int_0^\infty \left\{ \exp\left(xt\cos\theta_r - \frac{t^{2n+1}}{2n+1}\right) \right\} \sin(xt\sin\theta_r)\, dt$$

$$- \sin\theta_r \int_0^\infty \exp\left(-xt - \frac{t^{2n+1}}{2n+1}\right) dt \tag{11}$$

where $r = 0, 1, \ldots, n-1$ furnish $2n$ real distinct solutions and hence form a complete class.

CASE II. $k = 2n + 1$

In this case. the differential equation is

$$y^{(2n+1)} + x\ y = o, \tag{12}$$

and the corresponding values of ω are given by $\omega^{2n+2} = -1$, so that $\omega = e^{\pm i\varphi_r}$ where.

$$\varphi_r = \frac{2r+1}{2(2n+1)}\pi \ : r = o,1,\ldots,n.$$

Again using the notation (5), the complete primitive may be written

$$y = \sum_{r=o}^{n} A_r\ e^{i\varphi_r} F_{2n+1}(x\ ; e^{i\varphi_r}) +$$

$$\sum_{r=o}^{n} \beta r\ e^{-i\varphi_r} F_{2n+1}\ (x\ ; e^{-i\varphi_r}),$$

where the $2n+2$ arbitrary constants A_r, B_r are conneeted by the relation

$$\sum_{r=o}^{n} (A_r + B_r) = o\ ,$$

which evidently reduces their number by 1.

3. THE SECOND CLASS OF DEFINITE INTEGRAL SOLUTIONS

This class is characterized by choosing ω so as to satisfy the two conditions .

$$Rl\ \omega^{k+1} = o\ , \tag{13}$$

$$x\ Rl\ \omega < o. \tag{14}$$

No generality is lost if condition (13) is replaced by.

$$\omega^{k+1} = \pm i$$

The merit of this is simplify the form of the solution. For the convenience of reference, we refer to this condition by T (k, ω) and to condition (14) by L (x, ω) .

The values of ω satisfying the conditions T (k,ω) and L (x,ω) differ according as k, k-1, k-2, k-3 is divisible by 4. For this reason, each of these cases is considered seperately . We deal, for the sake of simplicity, with the second and fourth and then with the first and third cases.

C A S E I. $k = 4m + 1$

In this case the differential aquation is

$$y^{(4m+1)} + x\,y = o .$$

and T (4m+1,ω) : $\omega^{4m+2} = \pm i$

is evidently satisfied by $\omega = e^{\pm i \alpha_r}$, where

$$\alpha_r = \frac{4r+1}{4(2m+1)}\pi , \quad r = 0, 1, \ldots, 4m+1$$

Moreover L (x, ω) implies

$r = m + 1, m + 2, \ldots, 3m + 1$ when $x > 0$,

and $r = 0,1, \ldots, m, 3m + 2, 3m + 3, \ldots, 4m + 1$ when $x < 0$.

Then the complete primitive may be written

$$y = \sum_r A_r e^{i\alpha_r} F_{4m+1}(x; e^{i\alpha_r}) +$$

$$\sum_r B_r e^{-i\alpha_r} F_{4m+1}(x; e^{-i\alpha_r}),$$

where the summation ranges over the values of r cited above and the 4m + 2 constants A_r , B_r are reduced to 4m + 1 only through the relation

$$\sum_r (A_r + B_r) = o$$

CASEII. $k = 4m + 3$

In this case the differential equation is

$$y^{(4m+3)} + x\,y = o$$

and

$$T(4m+3, \omega) : \omega^{4m+4} = \pm i$$

is evidently satisfied by $\omega = e^{\pm i\beta_r}$ where.

$$\beta_r = \frac{4r+1}{8(m+1)}\pi, \quad r = o, 1, \ldots, 4m+3$$

Moreover $L_r(x,\omega)$ implies

$r = m+1, m+2, \ldots, 3m+2$ when $x > 0$,

and $r = 0, 1, \ldots, m, 3m+3, 3m+4, \ldots, 4m+3$ when $x < 0$.

The complete primitive then takes the form

$$y = \sum A_r\, e^{i\beta_r} F_{4m+3}(x; e^{i\beta_r}) + \sum_r \beta_r\, e^{i\beta_r} F_{4m+3}(x; e^{-i\beta_r})$$

where the summation is taken over the values of r cited above and the 4m+4 arbitrary constants A_r, β_r are reduced to 4m+3 only through the relation.

$$\sum_r (A_r + \beta_r) = o$$

Before we proceed to the remaining two cases namely when $k = 4m$ and $k = 4m + 2$, we give the following two lemmas.

Lemma 1 : The series solution of the differential equation

$$y^{(2n)} + x\,y = o$$

is

$$y = \sum_{p=o}^{2n-1} a_p x^p \sum_{r=o}^{\infty} \frac{(-)^r (2n+1)^r}{(2nr + r + p)!} \Gamma\left(r + \frac{p+1}{2n+1}\right) x^{r(2n+1)}$$

where a_o, a_1, ..., a_{2n-1} are arbitrary constants.

This can be obtained directly from the series solution of the differential equation $y^{(k)} - xy = o$, where $k = 2n$, by just replacing x by - x. (Cf. [1], § 1).

Lemma 2. With the notation introduced in (5), the definite integral

$$F_{2n}(x; \pm i) = \int_o^\infty \exp\left\{ i\left(\pm xt + \frac{t^{2n+1}}{2n+1} \right) \right\} dt,$$

where the + or — sign is taken according as n is even or odd, satisfies the differential equation

$$y^{(2n)} + xy = o$$

Proof: Consider the integral of $\exp i\left(\pm x\xi + \frac{\xi^{2n+1}}{2n+1}\right)$ taken along the contour which consists of the real t - axis from o to R, the arc of the circle $|\zeta| = R$, $o \leqslant \arg \xi \leqslant \alpha = \frac{\pi}{2(2n+1)}$ and the radius vector $\xi = \tau e^{i\alpha}$ from $\tau = R$ to $\tau = o$. The integral along this arc tends to zero as R teuds to infinity. Hence by Cauchy's theorem

$$\int_o^\infty \exp\left\{ i\left(\pm xt + \frac{t^{2n+1}}{2n+1} \right) \right\} dt$$

$$= e^{i\alpha} \int_o^\infty \exp\left\{ i\left(\pm x\tau e^{i\alpha} + i\,\frac{\tau^{2n+1}}{2n+1} \right) \right\} d\tau$$

But $\alpha = \pi/2\,(2n+1)$ and therefore

$$i\,e^{i\alpha} = e^{2(n+1)i\alpha}, \quad ie^{i(2n+1)\alpha} = -1$$

then by using the adopted notation for $F_{2n}(x; \pm i)$, it follows that

$$F_{2n}(x; \pm i) = e^{i\alpha} \int_o^\infty \exp\left\{ -\frac{\tau^{2n+1}}{2n+1} \pm x\,\tau\, e^{2(n+1)i\alpha} \right\} d\tau$$

$$= e^{i\alpha} \sum_{m=o}^{\infty} e^{2m(n+1)i\alpha} \frac{(\pm x)^m}{m!} \int_o^\infty \tau^m \exp\left(-\frac{\tau^{2n+1}}{2n+1}\right) dt$$

$$= e^{i\alpha} \sum_{m=o}^{\infty} e^{2m(n+1)i\alpha} \frac{(\pm x)^n}{m!} (2n+1)^{\frac{m-2n}{2n+1}}\, \Gamma\left(\frac{m+1}{2n+1}\right)$$

Now if we write $m = r(2n+1) + p$ with $o \leqslant p \leqslant 2n$ we have

$$F_{2n}(x; + i) = \sum_{p=o}^{2n} a_{n,p} x^p \sum_{r=o}^{\infty} (\pm)^r$$

$$\frac{e^{i(n+1)\pi r} (2n+1)^r x^{r(2n+1)}}{\{r(2n+1)+p\}!} \Gamma\left(r + \frac{p+1}{2n+1}\right)$$

where

$$a_{n,p} = (\pm)^p (2n+1)^{\frac{p-2n}{2n+1}} e^{\{2p(n+1)+1\} i \alpha},$$

and the result then follows from lemma (1) if we observe that

$e^{i(n+1)\pi r} = (-)^r$ when n is even,

and $e^{i(n+1)\pi r} = +1$ when n is odd.

We now return to the remaining two cases.

CASE III : $k = 4m$.

In this case the differential equation is

$$y^{(4m)} + x y = 0$$

and

$$T(4m, \omega) : \omega^{4m+1} = \pm i$$

which is evidently satisfied by $\omega = e^{\pm i \gamma_r}$, where

$$\gamma_r = \frac{4r+1}{2(4m+1)} \pi : r = 0, 1, 2, \ldots, 4m$$

Moreover $L(x, \omega)$ implies directly

$r = m+1, m+2, \ldots, 3m$ when $x > 0$,

and $r = 0, 1, \ldots, m-1, 3m+1, 3m+2, \ldots, 4m$ when $x < 0$.

Thus by using lemma (2), we see that a primitive of the given differential equation is

$$\sum_r A_r e^{i\gamma_r} F_{4m}(x; e^{i\gamma_r}) + A_m i F_{4m}(x; i),$$

provided that

$$A_m + \Sigma A_r = 0$$

Hence

$$\sum_r A_r e^{i\gamma_r} \{ F_{4m}(x; e^{i\gamma_r}) - i e^{-i\gamma_r} F_{4m}(x; i), \}$$

with A_r being arbitrary constants, is a primitive . Therefore

$$y = F_{4m}(x; e^{i\gamma_r}) - i e^{-i\gamma_r} F_{4m}(x; i)$$

$$= \int_0^\infty \exp\left\{ xte^{i\gamma_r} + \frac{it^{4m+1}}{4m+1} \right\} dt +$$

$$e^{-i(\gamma_r + \frac{\pi}{2})} \int_0^\infty \exp\left\{ i\left(xt + t\frac{4m+1}{4m+1} \right) \right\} dt$$

where r takes one of the values cited above, is a primitive. Splitting this primitive into its real and imaginary parts in the form.

$$C_{4m}(x; \gamma_r) + i S_{4m}(x; \gamma_r)$$

we get the 4m distinct solutions, namely,

$$C_{4m}(x; \gamma_r) = \int_0^\infty x t \cos\gamma_r \cos\left\{ x t \sin\gamma_r + \frac{t\, 4m+1}{4m+1} \right\} dt$$

$$+ \int_0^\infty \sin\left\{ x t + \frac{t\, 4m+1}{4m+1} - \gamma_r \right\} d t$$

$$S_{4m}(x;\gamma_r) = \int_0^\infty e^{xt\cos\gamma_r} \sin\left\{xt\sin\gamma_r + \frac{t^{4m+1}}{4m+1}\right\} dt$$

$$+ \int_0^\infty \cos\left\{xt + \frac{t^{4m+1}}{4m+1} - \gamma_r\right\} dt$$

where the values of r are as indicated before.

CASE IV. $k = 4m + 2$.

In this case the differential equation is

$$y^{(4m+2)} + xy = o$$

and $T(4m+2, \omega) : \omega^{4m+3} = \pm i$

which is evidently satisfied by $e^{\pm i\delta_r}$, where

$$\delta_r = \frac{4r+1}{2(4m+3)}\pi, \quad r = o, 1, \ldots, 4m+2$$

Moreover $L(x,\omega)$ implies that

$r = m+1, m+2, \ldots, 3m+1$ when $x > 0$

and $r = 0, 1, \ldots, m, 3m+3, 3m+4, \ldots, 4m+2$ when $x < 0$.

Thus using again lemma (2), we see that a primitive of the differential equation is

$$\Sigma_r A_r e^{i\delta_r} F_{4m+2}(x; e^{i\delta_r})$$

$$- A_{3m+2}\, i\, F_{4m+2}(x; -i),$$

provided that

$$A_{3m+2} + \sum_r A_r = o$$

hence

$$\Sigma_r A_r e^{i\delta_r} \{ F_{4m+2}(x ; e^{i\delta_r})$$

$$+ ie^{-i\delta_r} F_{4m+2}(x;-i)\}$$

with A_r being arbitrary constants, is a primitive. Therefore

$$y = F_{4m+2}(x;e^{i\delta_r}) + i e^{-i\delta_r} F4_{4m+2}(x; i),$$

is also a primitive. Writing this primitive in the form

$$C_{4m+2}(x:\delta_r) + i S_{4m+2}(x ; \delta_r),$$

and uaing (5), we see that

$$C_{4m+2}(x;\delta_r) = \int_o^\infty e^{xt\cos\delta_r} \cos\left\{ xt\sin\delta_r + \frac{t^{4m+3}}{4m+3}\right\} dt$$

$$+ \int_o^\infty \sin\left\{ xt - \frac{t^{4m+3}}{4m+3} + \delta_r \right\} dt$$

and

$$S_{4m+2}(x;\delta_r) = \int_o^\infty e^{xt\cos\delta r} \sin\left\{ xt \sin\delta_r + \frac{t^{4m+3}}{4m+3}\right\} dt$$

$$+ \int_0^\infty \cos\left\{ xt - \frac{t^{4m+3}}{4m+3} + \delta_r \right\} dt$$

give, for the values of r indicated before, 4 m + 2 real distinct solutions.

REFERENCE

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ON FINITE GROUPS WITH TWO INDEPENDENT GENERATORS

By

K. K. YACOUB

In This paper, I describe completely all the finite groups with two independent generators one of which being of order 9. Such groups are in fact the general products of two cyclic groups $\{a\}$ and $\{b\}$ when one of them say $\{b\}$ is of order 9. These general products have been readily described by the author [Cf. $]. There are 5 types of such general prouducts namely :

$G_1 : \{ a, b; a^m = b^9 = e, ab = b a^r , r^9 \equiv 1 \pmod m \}$

$G_2 : \{ a, b, a^m = b^9 = e, ab = b^2 a , 6' \mid m \}$

$G_3 ; \{ a, b, a^m = b^9 = e, ab = b^4 a^{3t+1}, a^3 b = b a^{3(3t+1)} \}$
where $3 \mid m$, $3(3t+1)^3 \equiv 3 \pmod m$

$G_4 . \{ a, b, a^m = b^9 = e, ab = b^8 a , m$ even

$G_5 . \{ a, b, a^m = b^9 = e, ab = b^2 a^{2M+1} ,$

$a b^3 = b^6 a^{6M+1} , a^6 b = b a^6 \}$

where $m = 6M, (M,3) = 1, M' = \pm M, M' = 1 \pmod 3$
or $m = 18M, (M,3) = 1, M' = \pm M, M' = 1 \pmod 3$

For the description of these groups the reader is referred to [1]. It is object of this note to distinguish for isomorphism the non-isomorphic types of groups.

Theorem 1 : G_5 is of the type G_2.

For if G_5 is generated by c and d where $c = a^{-1}$, $d = b\, a^{2M}$, then its defining relations will be

$$c^m = d^9 = e \,,\; c\, d = d^2\, c$$

Thus G_5 is of the type G_2 .

Theorem 2 : No group of the type G_1 is isomorphic to G_2 or G_4 .

Proof ; If G_1 is isomorphic to G_2 . then G'_1 and G'_2 will have the same order. Thus $m/(m, r-1) = 9$. where 6 divides m. Thus $m = 18$ M. say, and $r = 1 + 2\,\theta\, M \pmod m$ where $(\theta, 3) = 1$. The centre of G_1 ie then generated by a^9 and possibly b^3. while the centre of G_2 is $\{a^6\}$. Thus G_1 cannot be isomorphic to G_2 .

Similary G_1 is not isomorphic to G_4 .

Theorem 3 : No group of the type G_3 is isomorphic to G_2 or G_4 .

Proof : If G_2 is isomorphic to G_3 . then $G'_3 = \{b^3\ a^{3t}\}$ wl have the same orde as $G'_2 = \{b\}$ which is 9. Thus $27t \equiv 0$, but $9t \not\equiv 0 \pmod m$.

Then the centre of G_3 is $\{a^9\}$ while the centre of G_2 is $\{a^6\}$. Thus G_3 cannot be isomorphic to G_2.

Similariy it can be shown that G_3 is not isomorphic to G_4.

Theorem 4 : G_2 is not isomorphic to G_4.

For the centre of G_2 is $\{a^6\}$ and the centre of G_4 is $\{a^2\}$, their orders are $m/6$ and $m/2$ respectivly . Thus G_2 is not isomorphic to G_4 .

Finally, to distinguish for isomorphism G_1 and G_3 , we prove the followin

Theorem 5 : Let G and H be two groups whose defining relations are .

$G : \{ a, b, a^m = b^9 = e, ab = b a^r , r^9 \equiv 1 \pmod m.$

$H : \{ a', b' \; a'^m = b'^9 = e, a'b' = b'^4 a'^{3t+1} \quad a'^3 b' = b'a'^{3(3t+1)}$

where $m = 3^u M$, $u \geqslant 1$, $(M,3) = 1$ and $3(3t+1)^3 \equiv 3 \pmod m$. Then G is isomorphic to H if and only if

$$u = 2 \text{ or } 3$$

and $(m, r-1) = (m, 3t) = h$

where $h = m/3$ or $m/9$ according as $u = 2$ or 3.

Proof: The proof of the theorem is rather long and we give here only the main lines of the proof. Suppose now that G is isomorphic to H. Then $G' = \{ a^{r-1} \}$ and $H' = \{ b'^3 \; a'^{3t} \}$ will be isomor phic. But it is easy to show that $b'^3 a'^{3t}$ cannot be a 9 th power and hence r-1 is not divisible by 9. Moreover $r^9 \equiv 1 \pmod m$ imrlies $r^9 \equiv 1 \pmod{3^u}$, thus $r \equiv 1 \pmod{3^{u-2}}$ and then $u-2 < 2$. i. e. $u < 4$. If $u = 1$, then the 3-Sylow subgroup of G fs Abelian, while the Sylow supgroup of H is not Abelian . Thus is what follows $u = 2$ or 3 .

In H. we can show by direct calculation that.

$$(a'^x b'^y)^3 = b'^{3y} a'^{3xS} . (a'^x b'^y)^9 = a'^{9xS}$$

where $S \equiv 1 + 3t + 3t^2 \pmod m.$

In the isomorphism of G and H,let $a \longleftrightarrow a'^x b'^y$. If y is divi sible by 3. then $a \longleftrightarrow a'^{3x'}$ for some x, also since $r \equiv 1 \pmod 3$ then a^{r-1} cannot be mapped on $b'^3 a'^{3t}$ contrary to the

isomorphism of G'and H'. Thus $a \longrightarrow a'^{x} b'^{y}$ where $(y,3) = 1$, and accordingly $a^{9} \longleftrightarrow a'^{9x} S$, but since a^{9} is of order $m/9$, and since $27\ t\ s = 0 \pmod{m}$, then

$$27\ t \equiv 0 \pmod{m}, \text{ i.e. } 3t \equiv 0 \pmod{3M}.$$

Also since G and H have the same order, then

$$(m, r-1) = (m, 3t) = h, \text{ say.}$$

For $u = 2$, the order of H' (and hence of G') is 3, thus $r = 1 + 3Mk$ where $(k,3) = 1$. In this cass $h = 3M = m/3$.

Then let $u = 3$. Since $3t \not\equiv 0 \pmod{3M}$, then M divides h. also as $r-1 \equiv 0 \pmod{3}$, but $r-1 \not\equiv 0 \pmod{9}$, then $r = 1 + 3Mk$ where $(k,3) = 1$. In this case $h = 3M = m/9$.

Thus we have shown that the condition is necessary.

Conversely if $(m, r-1) = (m, 3t) = h$, where $h = m/3$ or $m/9$ according as $u = 2$ or 3, then we can write

$$r = 1 + 3M\,k, \quad t = 3M\,k'$$

where **k** and **k'** are both prime to 3.

Now let $M' = \pm M$ and $M' \equiv 1 \pmod{3}$.

For $u = 3$, if $r = 1 + 3M'k$, $r \equiv 1 + 3M' \pmod{m}$; then it can be shown that there exists a number θ such that $r \equiv r'^{\theta} \pmod{m}$ and $(\theta, 3) = 1$.

In this case, the groups arising from G corresponding to these values r and r' are isomorphic.

Again if $3t+1 = 3M'k' + 1$ and $3t'+1 = 3M'+1$, then

$$3t'+1 \equiv (3t+1)^{\theta} \pmod{m/3} \qquad \text{for } \theta = 1 \text{ or } 2.$$

and the groups arising from H corresponding to these values of t and t, are isomorphic.

Thus it is sufficient to verify the isomorphism of G and H when

$$r = 1 + 3M', \quad 3 = 3M' \pmod{m}, \quad u = 2 \text{ or } 3.$$

In this case, the isomorphism is established by the correspondence

$$a = a' b' , b \longleftrightarrow b'^4 .$$

This is completes the proof of the theorem.

Summary

From the previous results. we conlude that a finite group with two independent generators, one of which being of order 9, must be of the type G_1 , G_2 , G_3 or G_4. The possible types of groups that can be isomorphic are G_1 and G_3 but all other types of groups cannot be isomorphic.

Reference

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TETRAD VECTOR FIELDS AND GENERALIZING THE THEORY OF RELATIVITY

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I. INTRODUCTION

1. Need to Extend Relativity Theory :

One of the main aspects in which the general theory of relativity differs from other field theories is that it involves the use of the geometrical structure of space. In formulating his well-known equations .

$$R_{\mu\nu} - \tfrac{1}{2} g_{\mu\nu} R = - K T_{\mu\nu} \qquad (1.1)$$

Einstein has made use of the structure of a 4-dimensional Riemannian space . This ordinary Riemannian space - derived from a symmetric fundamental tensor $g_{\mu\nu}$ - does not give rise to any tensors, which may be used for physical representations, other than the Ricci tensor $R_{\mu\nu}$ used in (1.1) (Cf. (3), p. 79) . As these relations are regarded to be purely gravitational, it seems ,therefore necessary to extend the geometrical structure of general relativity in order to be able to represent any other physical phenomenon .

The need to extend the field-structure, upon which equations (1.1) are based, has in fact arisen in more than one occasion . The numerous attempts, initiated by H. Weyl in 1918 (18), to generalize Einstein's relativistic theory of gravitation so as to take account in the same natural way of electromagnetic forces are well-known.

In quite a different occasion, R. C. Tolman (17) has considered,

the modification of relations (1.1) so as to give rise to a non-conservative sort of mechanics which will enable a local observer to describe physical processes leading to the creation or destruction of energy inside the matter in his neighbourhood. A similar modification has been considered by F. Hoyle (10,11) in connection with the "continuous creation of matter" postulated in recent cosmological investigations.

Lastly, we may mention the various extensions made in attempt to quantize general relativity. The works of Bergmann, Fauli and Rosenfeld in this connection are well known.

2. Types of Extensions :

In these different sets of considerations authors have sought a variety of ways in extending the field-structure used for the representations of general relativity. In several cases the Riemannian space is retained, but it is assumed to admit an extra vector-field of a particular type. In other cases, the capabilities of the space are increased by deriving it from a tetrad vector field (16 components) in place of the ordinary metric tensor (10 components). In recent generalizations, the original Riemannian space is replaced by a non-Riemannian one based on a general affine-connection which is in turn defined in terms of a non-symmetric second order tensor (16 components).

As a result of these varied and unrelated efforts to modify the general theory of relativity, we have a variety of spaces leading to a variety of field-equations and each set is claimed to represent a generalization of the theory. In other words, we have, in fact, not one generalized theory but a set of theories each of which is formulated for a particular purpose that may be within the reach of the others. We believe, however, that these different types of extensions are so linked together that any mathematical procedure dealing with one type is almost certain to yield the others.

Our belief is not without foundation, as in most of these generalizations the main interest was in some tensors to the neglect of all others. In fact, authors were only content in obtaining some plausible field-relations, expressing the idea under consideration, without any thorough examination of the intrinsic properties of the geometrical

structure used in the formalism of their suggested theories. For instance, Einstein (4) using a tetrad field, was only content in deriving a vector and one skew-tensor that he used in the formalism of his first unified field-theory. Levi-Civita (12,13)*[1] using the same space but following a different procedure, has only derived the same vector and two other skew tensors. (We shall show below, following either of these two different procedures, that this same space has actually a set of five skew and seven symmetric tensors beside the basic vector derived by Einstein and Levi - Civita). Also F. Hoyle (11) has adopted for his creation tensor the symmetric part of a second order tensor [equation (10)] and left its skew part without any physical interpretation. As these neglected tensors are usually of the same order and simplicity as those used in the formalism, they ought to be given equal consideration and to have some physical significance. They may be useful in the representations of some physical phenomena other than the particular one under consideration. It would be expected, however, that a satisfactory field - theory should afford some physical significance to each of its derived members unless there are some definite reasons for rejecting it.

3. One Single Generalization

This shows clearly that it is of great mathematical as well as physical interest to investigate whether there is one single space capable of producing results similar to those obtained in the above various cases, and thus providing one single generalization of Einstein's theory of gravitation. We have found that tetrad vector fields as defined below, possess this property. Using a Riemannian tetrad space, we have been able to give a more suitable treatment of the postulate of the "continuous creation of matter" (14). We have also been able, using a tetrad field, to derive a unified field theory** in close formal similarity with that given by Einstein (6,7).

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*The latter paper is an English translation of the original one and will be quoted hereafter as (L.C.)

** Mikhail, F.I., Il Nuovo Cimento, vol. 32, p.886 (1964)

However, we believe that tetrad-spaces; through their wealth of nomenclature, offer a natural and general way of extending the field-structure of general relativity.

Tetrad vector fields have been used before by several writers for various purposes. Einstein (4), Levi-Civita (12, 13), Weyl (19, 20, 21) and Yano and Ohgane (22) used them in attempts to formulate unified field-theories. More recently, Bergmann and Thomson (1) have used them to treat spin and angular momentum in relativity theory. It is also of some interest to refer here to the new application of orthogonal vector-fields introduced recently by Bilby and others (2). They have used orthogonal triplets in describing continuous distributions of dislocations in crystals.

The writers, quoted above, have used a variety of ways in describing the geometrical properties of orthogonal tetrad fields and in using them in the various physical applications. They have followed different procedures in describing the structure of the space used in their formalisms. Various types of absolute derivatives were defined and different tensors were derived.

The purpose of the present paper is to describe tetrad spaces in a simple and more unified way, and to relate the previous works to each other. All tensors of the second order, which may be used in physical applications, are derived.

II. FUNDAMENTAL PRELIMINARIES

4. Tetrad Space :

Starting with a four-dimensional vector-space continuum, we label each point of this continuum by means of a set of four independent variables x^{ν} ($\nu = 0,1,2,3$) - in the sense that each set of values of the variables defines a point. We then associate with each point of this space four linearly independent contravariant vectors λ_i^{μ} where μ ($= 0,1,2,3$) indicates the co-ordinate component and i ($= 0,1,2,3$) indicates the vector.

The components λ_i^μ are assumed to be one-valued functions of the co-ordinates x^ν and differentiable to any required order.

Consequently the equations

$$\frac{d\ x^\mu}{d\ s^i} = \lambda_i^\mu \ (\mu = 0,1,2,3) \tag{4·1}$$

where for the present the parameter s^i is not otherwise defined, determine a congruence of curves in the vector-space continuum. The four congruences ($i = 0,1,2,3$) form what we shall call the **mesh**. From (4.1) we get the differential operator,

$$\frac{d}{ds^i} \equiv \lambda_i^\nu \frac{\partial}{\partial\ x^\nu} \tag{4.2}$$

which, when acting on any invariant function of the co-ordinates, $f(x^\nu)$ say, gives its intrinsic derivative along the curves of the mesh.

In the following, we shall denote tensor-suffixes by Greek letters and mesh-suffixes by Latin letters; and we shall apply the summation convention to both sets.

Denoting by $\lambda^i{}_\mu$ the normalized cofactor of λ_i^μ in the determinant $\left|\lambda_i^\mu\right|$ we have

$$\lambda_i^\mu\ \lambda^k{}_\mu = \delta_i^k \tag{4.3}$$

$$\lambda_i^\mu\ \lambda_\nu^i = \delta_\nu^\mu \tag{4.4}$$

in which the right-hand members are Kronecker deltas. Mesh-suffixes will be raised or lowered, when necessary, to effect the summation convention. It is to be noted that relations (4.3), (4.4) are of a reciprocal character. That is, if we had started with the covariant vectors λ_μ^i they would serve to define their conjugate contravariant vectors.

Any space whose structure is defined by means of such a tetrad vector field in the sense described above, will be called a tetrad space and will be denoted by T_4.

5. Mesh-Tensors :

By composition with the components of the vectors $(\lambda_i^\mu, \lambda_\mu^i)$ we obtain from any tensor $A_{\mu\upsilon}{}^\sigma$, say, a set of invariants defined by

$$A_{ih}{}^k = A_{\mu\upsilon}{}^\sigma \ \lambda_i^\mu \ \lambda_h^\nu \ \lambda^k{}_\sigma \qquad (5.1)$$

Using (4.4), these will give

$$A_{\mu\upsilon}{}^\sigma = A_{ih}{}^k \ \lambda^i_\mu \ \lambda^h{}_\upsilon \ \lambda^\sigma_k \qquad (5.2)$$

A set of invariants such as $A_{ih}{}^k$ will be called a **mesh-tensor** of the third order. In general, mesh-tensors behave like tensors only with respect to orthogonal transformations with constant coefficients of λ_i^μ and are then called local mesh-tensors.

Contracting (5.2) for σ and υ, we notice that the contraction of a world-tensor results in a contraction of the associated mesh-tensor in the following manner.

$$C_\mu \equiv A_{\mu\upsilon}{}^\upsilon = A_{ih}{}^k \ \lambda^i_\mu \ \lambda^h{}_\upsilon \ \lambda_k{}^\upsilon$$

$$= A_{ih}{}^h \ \lambda^i_\mu \qquad (5.3)$$

$$C_i \ \lambda^i{}_\mu$$

where

$$C_i = A_{ih}{}^h \qquad (5.4)$$

A mesh-tensor is symmetric (skew) in a pair of suffixes if and only if the associated world-tensor is symmetric (skew) in the corresponding suffixes. This is easily seen from relatious (5.1), (5.2).

6. A Symmetric Tensor :

The set of quantities $g_{\mu\nu}$ defined by

$$g_{\mu\upsilon} = \lambda_{i}^{\mu} \lambda_{\upsilon}^{i} \tag{6.1}$$

forms a symmetric covariant tensor of the second order. This is easily seen by noting that

$$\lambda_{h}^{\upsilon} g_{\mu\upsilon} = \lambda_{i}^{\mu} \lambda_{\upsilon}^{i} \lambda_{h}^{\upsilon} = \lambda_{i}^{\mu} \delta_{h}^{i} = \lambda_{h}^{\mu} \tag{6.2}$$

using (4.3). Denoting by $g^{\mu\upsilon}$ the normalized cofactor of $g_{\mu\upsilon}$ in the determinant $|g_{\mu\nu}|$, we have

$$g_{\mu\sigma} \; g^{\upsilon\sigma} = \delta_{\mu}^{\upsilon} \tag{6.3}$$

showing that the set $g^{\mu\upsilon}$ forms a contravariant tensor.

The symmetric tensor $g_{\mu\upsilon}$ with its conjugate $g^{\mu\upsilon}$ provide us with a process of lowering and raising indices in the usual way. In particular, raising indices in (6.1) we get

$$g^{\mu\upsilon} = \lambda_{i}^{\mu} \lambda^{i} / \upsilon \tag{6.4}$$

The tensor $g_{\mu\nu}$, being symmetric can be used as a **metric tensor** if the tetrad - space is required to be Riemannian. Thus, the metric of a Riemannian T_4 will be

$$ds^2 = g_{\mu\nu} \, dx^{\mu} \, dx^{\nu}, \tag{6.5}$$

with $g_{\mu\nu}$ defined by (6.1) In this case the tetrad vectors will form a set of orthogonal unit vectors, since

$$\begin{aligned} g_{\mu\nu} \lambda^{\mu} \lambda_{k}^{\nu} &= \lambda_{h}^{\mu} \lambda^{h}{}_{\nu} \lambda_{i}^{\mu} \lambda_{k}^{\nu} \\ &= \delta_{hi} \, \delta^{h}{}_{k} \\ &= \delta_{ik} \end{aligned} \tag{6.6}$$

Description of the Space :

We shall describe the tetrad space in two different ways. In the first, we shall use a symmetric affine-connection, and we shall derive the various tensors of the space in the form of mesh-tensors. In the second, we shall use a non-symmetric connection, and we shall show that these two different procedures of describing tetrad spaces are equivalent in the sense that they both give rise to the same set of tensors.

This treatment has also an interesting result. It shows the equivalence of the two procedures used by Einstein (4) and Levi-Civita (12) in spite of their formal differences.

III. SYMMETRIC AFFINE - CONNECTION.

8. The Connection :

We choose as our symmetric affine - connection the quantities

$$\left\{ \begin{matrix} \sigma \\ \mu\nu \end{matrix} \right\} = \tfrac{1}{2}\, g^{\sigma\alpha} \left(\frac{\partial g_{\mu\alpha}}{\partial x^{\nu}} + \frac{\partial g_{\nu\alpha}}{\partial x^{\mu}} - \frac{\partial g_{\mu\nu}}{\partial x^{\alpha}} \right). \qquad (8.1)$$

which are the ordinary Christoffel symbols of the second kind. It is well-known that there is a **single** absolute derivative associated with this symmetric connection. Denoting this absolute differentiation by a semicolon, it is also well-known that

$$g_{\mu\nu}\ ;\ \sigma \equiv 0\,, \qquad g^{\mu\nu}\ ;\ \sigma \equiv 0. \qquad (8.2)$$

Hence we can raise or lower indices under the differentiation sign.

9. A Tensor of the Third Order :

In accordance with (5.1), we form the mesh-tensor

$$\gamma_{ihk} = \lambda_{i\mu\nu}\, \lambda^{\mu}_{h}\, \lambda^{\nu}_{k} \qquad (9.1)$$

where $\lambda_{i\mu\nu}$ (or $\lambda^{i}{}_{\mu\nu}$) denotes the derivative of $\lambda^{i}{}_{\mu}$ with respect

to the symmetric connection (8.1). The components of this tensor are Ricci's cofficients of rotation. Equations (9.1) can be solved to give

$$\lambda_{i\mu\nu} = \gamma_{ihk}\ \lambda^{h}_{\mu}\ \lambda^{k}_{\nu} \tag{9.2}$$

The world-tensor associated with (9.1) is

$$\begin{aligned}\gamma_{\sigma\mu\upsilon} &= \gamma_{ihk}\ \lambda^{i}_{\sigma}\ \lambda^{h}{}_{\mu}\ \lambda^{k}{}_{\nu} \\ &= \left(\lambda_{i\alpha\beta}\ \lambda^{\alpha}_{h}\ \lambda^{\beta}_{k}\right) \lambda^{h}{}_{\mu}\ \lambda^{k}{}_{\nu}\ \lambda^{i}{}_{\sigma} \\ &= \lambda^{i}{}_{\sigma}\ \lambda_{i\mu\nu}\end{aligned} \tag{9.3}$$

Thus

$$\begin{aligned}\gamma_{\sigma\mu\upsilon} + \gamma_{\mu\sigma\upsilon} &= \left(\lambda^{i}_{\sigma}\ \lambda_{i\mu}\right) ;\ \upsilon \\ &= g_{\sigma\mu}\ ;\ \upsilon = 0\end{aligned} \tag{9.5}$$

which shows that $\gamma_{\sigma\mu\upsilon}$ and so also γ_{ihk} are skew-symmetric in the first two indices. From (9.3), we have

$$\gamma^{\sigma}{}_{\mu\upsilon} = \lambda^{\sigma}_{i}\ \lambda^{i}{}_{\mu\upsilon} \tag{9.5}$$

10. A Basic Vector :

Considering the divergence of the tetrad vectors, we introduce the basic mesh-vector

$$C_i = -\left(\lambda^{\nu}_{i}\right) ;\ \nu \tag{10.1}$$

The negative sign has been chosen to identify C_i with Levi - Civita's mesh-vector (L. C. equation 14). This identification follows directly since

$$\begin{aligned}C_i &= -\ g^{\mu\nu}\ \lambda_{i\mu\upsilon} \\ &= -\ \lambda^{\mu}_{h}\ \lambda^{h/\upsilon}\ \lambda_{i\mu\nu} \\ &= -\ \gamma_{ih}{}^{h} = \gamma_{hi}{}^{h}\end{aligned} \tag{10.2}$$

The world-vector corresponding to C_i is given by

$$C_\mu = C_i \lambda^i{}_\mu$$
$$= - \left(\lambda^\nu_i \right)_{;\nu} \lambda^i_\mu$$
$$= \lambda^\nu_i \lambda^i{}_{\mu\nu} \tag{10.3}$$

as a result of differentiating (4.4).

From (9.5) and (10.3), it is easily seen that C_μ is the same vector to be obtained by contracting $\gamma^\sigma{}_{\mu\nu}$ on σ, ν, viz.

$$C_\mu = \gamma^\nu{}_{\mu\nu} \tag{10.4}$$

Owing to the skew-symmetry of $\gamma_{\sigma\mu\nu}$ it can easily be verified that

$$\gamma^\sigma{}_{\sigma\nu} = 0 \tag{10.5}$$

and that

$$\gamma^\sigma{}_{\mu\nu} = - \gamma^\sigma_{\mu.\nu} \tag{10.6}$$

11. Mesh-Tensors of the Second Order :

As we are examining tetrad-spaces for physical representations, we shall only be concerned here with tensors of the second order. The fundamental mesh-elements obtained above are :

(i) the local vector C_i ,

(ii) the local tensor γ_{ihk},

(iii) the differential operator $\frac{d}{d s^i} \equiv \lambda^\nu_i \frac{\partial}{\partial x^i}$

From these, we can form the following tensors

$$\frac{dC_i}{d\,s^k},\ C_m\ \gamma_{ihk},\ \frac{d\gamma_{ihk}}{d\,s^m},\ \gamma_{ijk}\ \gamma_{lmn}$$

of which the first is of the second order, the second and third are of the fourth order, and the fourth is of the sixth order. Considering their symmetric and skew-symmetric parts and contracting the last three in all possible ways, we get the following list of mesh-tensors.

TABLE I

MESH - TENSORS

Skew tensors	Symmetric tensors
$\xi_{ik} = \dfrac{d\ \gamma_{ik}{}^h}{d\ s^h}$	
$\zeta_{ik} = C_h\ \gamma_{ik}{}^h$	
$\eta_{ik} = C_h\ (\gamma^h{}_{ik} - \gamma^h{}_{ki})$	$\phi_{ik} = C_h\ (\gamma^h{}_{ik} + \gamma^h{}_{ki})$
$\varepsilon_{ik} = \dfrac{d\ C_i}{d\ s^k} - \dfrac{d\ C_k}{d\ s^i}$	$\theta_{ik} = \dfrac{d\ C_i}{d\ s^k} + \dfrac{d\ C_k}{d\ s^i}$
$K_{ik} = \gamma_{ih}{}^l\ \gamma^h{}_{lk} - \gamma_{kh}{}^l\ \gamma^h{}_{li}$	$\tilde{\omega}_{ik} = \gamma_{ih}{}^l \gamma^h{}_{lk} + \gamma_{kh}{}^l\ \gamma^h{}_{li}$
$\chi_{ik} = \dfrac{d}{d\ s^h}\ (\gamma^h{}_{ik} - \gamma^h{}_{ki})$	$\psi_{ik} = \dfrac{d}{d\ s^h}\ (\gamma^h{}_{ik} + \gamma^h{}_{ki})$
	$\omega_{ik} = \gamma_{ih}{}^l\ \gamma_{kl}{}^h$
	$\sigma_{ik} = \gamma^l{}_{hi}\ \gamma^h{}_{lk}$
	$G_{ik} = \frac{1}{2}(\psi_{ik} - \phi_{ik} - \theta_{ik}) + \omega$

Identity : $\eta_{ik} + \varepsilon_{ik} - \chi_{ik} \equiv 0$

where G_{ik} is the mesh - tensor associated with the Ricci tensor $G_{\mu\nu}$ obtained from the symmetric connection (8.1) in the usual way. The identity at the end of the table will be proved in the following section.

The above list comprises twelve independent tensors; five skew symmetric and seven symmetric. The Ricci tensor G_{ik} and the two skew tensors ξ_{ik}, η_{ik} are the only tensors given before by Levi-Civita (L. C. equations (10), (12), (15) with the same symbols). The other tensors have not been derived before.

It is to be noted that all the tensors in this list are either of the second order in the coefficients of rotation γ_{ihk} or of the first order in their intrinsic derivatives. It can be easily seen that these are the same orders involved in the Ricci tensor G_{ik} which, in general, plays an important part in the formalism of any generalized field-theory. It has also been found by examining particular examples (14), that these are the right orders of magnitude required in most physical applications [Cf. (8)].

It is clear that we can go on indefinitely forming more tensors of order two by starting with tensors of orders 6, 8, 10, ..., and contracting them twice, three times, four times, ..., in the same manner used above. Any tensor formed in this way, e.g.

$$A_i = \frac{\gamma_i^{ln} \; \gamma_{kn}^{m}}{ds^l \; d s^m}$$

$$B_{ik} = \gamma_i^{ln} \; \gamma_{kn}^{m} \; \frac{dC}{d^{sm}}$$

is easily seen to involve terms of a higher order. Besides, such complicated tensors amount actually to multiplying two or more tensors of the above list and contracting the resulting tensor. Consequently, they will

not be of any new physical significance.

However, limiting, ourselves to tensors involving only first derivatives sf the γ's and their second powers, we can say that the above list is complete.

12. An Identity :

The Ricci mesh-tensor

$$G_{ik} = G_{\mu\nu} \quad \lambda_i^{\mu} \lambda_k^{\nu} \tag{12.1}$$

can be put into the form

$$G_{ik} = - \frac{dC_i}{ds^k} + \frac{d\,\gamma^h{}_{ik}}{d\,s^h}$$

$$- C_l \quad \gamma^l{}_{ik} + \gamma_{ih}{}^l \quad \gamma_{kl}{}^h \tag{12.2}$$

[cf. L. C. equations (8), (10)]. But the Ricci world-tcnsor $G_{\mu\nu}$ is symmetric. Therefore G_{ik} is also symmetric in i and k. Noting that the last term in (12.2) is symmetric in i , k, the sum of the skew parts of the first three right-hand members of (12.2) must vanish identically. Hence, apart from a factor – 1/2, we get the identity

$$\left(\frac{dC_i}{ds_k} - \frac{dC_k}{ds^i} \right) - \frac{d}{ds^h} \left(\gamma^h{}_{ik} - \gamma^h{}_{ki} \right)$$

$$+ C_m \left(\gamma \quad {}_{ik} - \gamma^m{}_{ki} \right) \equiv 0$$

That is

$$\varepsilon_{ik} - \chi_{ik} + \eta_{ik} \equiv 0 \tag{12.3}$$

This identity, when put in terms of world-tensors, is the same as that given by Einstein [(4), equation (3a)]

IV. NON-SYMMETRIC AFFINE-CONNECTION

13. The Connection :

So far we have not imposed any restriction on the four vector-fields λ^{μ}_{i} ($i = 0, 1, 2, 3$) defining a T_4. According to Eisenhart [(9), page 48] the most general form of affine - connection that will make the four fields of the tetrad vectors λ^{μ}_{i} parallel fields is

$$\Gamma_{\mu\nu}{}^{\alpha} = \lambda_i{}^{\alpha} \frac{\partial \lambda^i{}_{\mu}}{\partial x^{\nu}} = - \lambda^i{}_{\mu} \frac{\partial \lambda^{\alpha}_{i}}{\partial x^{\nu}} \tag{13.1}$$

This is also the same connection used by Einstein (4) and Robertson (16) for describing tetrad - spaces.

There is a simple direct relation between the general affine-connection (13.1) and the symmetric connection (8.1). This relation follows from

$$\lambda^i{}_{\mu\nu} = \frac{\partial \lambda^i{}_{\mu}}{\partial x^{\nu}} - \left\{ \begin{matrix} \beta \\ \mu\nu \end{matrix} \right\} \lambda^i{}_{\beta}$$

Multiplying both sides by λ^{α}_{i} and summing for i, we get

$$\lambda^{\alpha}_{i} \lambda^i{}_{\mu\nu} = \Gamma^{\alpha}{}_{\mu\nu} - \left\{ \begin{matrix} \beta \\ \mu\nu \end{matrix} \right\} \delta^{\alpha}_{\beta}$$

Therefore

$$\Gamma^{\alpha}{}_{\mu\nu} = \left\{ \begin{matrix} \alpha \\ \mu\nu \end{matrix} \right\} + \gamma^{\alpha}{}_{\mu\nu} \tag{13.2}$$

Introducing Einstein's skew tensor $\Lambda^{\alpha}{}_{\mu\nu}$ [(4) equation (8)] defined by

$$\Lambda^{\alpha}{}_{\mu\nu} = \Gamma^{\alpha}{}_{\mu\nu} - \Gamma^{\alpha}{}_{\nu\mu}$$

$$= \gamma^{\alpha}{}_{\mu\nu} - \gamma^{\alpha}{}_{\nu\mu} \tag{13.3}$$

and denoting the symmetric part of the tensor $\gamma^{\alpha}{}_{\mu\nu}$ by

$$\Delta^{\alpha}{}_{\mu\nu} = \gamma^{\alpha}{}_{\mu\nu} + \gamma^{\alpha}{}_{\nu\mu}, \tag{13.4}$$

the symmetric and skew-symmetric parts of the affine-connection (13.1) will be given by

$$\Gamma^{\alpha}{}_{\underline{\mu\nu}} = \left\{ \begin{matrix} \alpha \\ \mu\nu \end{matrix} \right\} + \tfrac{1}{2}\, \Delta^{\alpha}{}_{\mu\nu} \tag{13.5}$$

$$\Gamma^{\alpha}{}_{\underset{\vee}{\mu\nu}} = \tfrac{1}{2}\, \Lambda^{\alpha}{}_{\mu\nu} \tag{13.6}$$

14. Absolute Derivatives:

There are two types of absolute differentiation associated with the non-symmetric connection (13.1). These we define by the following:

$$\left.\begin{aligned} A^{\mu}_{+\,;\,\nu} &= A^{\mu}{}_{,\nu} + \Gamma^{\mu}{}_{\alpha\nu}\, A^{\alpha} \\ A^{\mu}_{-\,;\nu} &= A^{\mu}{}_{,\nu} + \Gamma^{\mu}{}_{\nu\alpha}\, A^{\alpha} \end{aligned}\right\} \tag{14.1}$$

for a contravariant vector and by

$$\left.\begin{aligned} A_{\underset{+}{\mu}\,;\nu} &= A_{\mu,\nu} - \Gamma^{\alpha}{}_{\mu\nu}\, A_{\alpha} \\ A_{\underset{-}{\mu};\nu} &= A_{\mu,\nu} - \Gamma^{\alpha}{}_{\nu\mu}\, A_{\alpha} \end{aligned}\right\} \tag{14.2}$$

for a covariant vector, where the semicolon denotes absolute differentiation and the comma denotes ordinary partial differentiation. These two types of absolute differentiation are to be distinguished from that associated with the symmetric connection $\left\{ \begin{matrix} \alpha \\ \mu\nu \end{matrix} \right\}$ by the signs (+) and (—) appearing underneath tensor indices in the former.

The divergence of a vector with respect to $\Gamma^{\alpha}_{\mu\nu}$ can be related to its divergence with respect to $\left\{ {\alpha \atop \mu\upsilon} \right\}$ by

$$\left.\begin{aligned} A^{\upsilon}_{+}\,;\,\upsilon &= A^{\upsilon}{}_{;\upsilon} + C_{\alpha}\,A^{\alpha} \\ A^{\upsilon}_{-}\,;\,\upsilon &= A^{\upsilon}\,;\,\upsilon \end{aligned}\right\} \quad (14.3)$$

Definitions (13.1) for the affine connection are exactly the necessary and sufficient conditions for the vanishing of the (+) — derivatives of the tetrad vectors $\lambda^{i}{}_{\mu}$, λ^{μ}_{i} [Cf. (9) p. 48]. This is directly seen since, for instande,

$$\begin{aligned} \lambda^{i}{}_{\underset{+}{\mu;\nu}} &= \lambda^{i}{}_{\mu\,,\,\nu} - \Gamma^{\alpha}{}_{\mu\,\nu}\,\lambda^{i}{}_{\alpha} \\ &= \lambda^{i}{}_{\mu\,,\nu} - \lambda^{\alpha}_{k}\,\lambda^{i}{}_{\alpha}\,\lambda^{k}{}_{\mu,\nu} \\ &= \lambda^{i}{}_{\mu\,,\,\nu} - \delta_{k}{}^{i}\,\lambda^{k}{}_{\mu,\nu} \\ &= 0\,. \end{aligned} \quad (14:4)$$

Conversily if

$$\lambda^{i}{}_{\underset{+}{\mu}}\,;\,\nu = 0 \quad (14.5)$$

that is

$$\lambda^{i}{}_{\mu\,,\,\nu} - \Gamma^{\beta}{}_{\mu\,\nu}\;\lambda^{i}{}_{\beta} = o\,,$$

we multiply through by λ^{α}_{i} and sum for i , and we get

$$\lambda^{\alpha}_{i}\;\lambda^{i}{}_{\mu\,,\,\nu} - \Gamma^{\beta}{}_{\mu\nu}\,\delta^{\alpha}{}_{\beta} = o$$

Hence

$$\Gamma^{\alpha}{}_{\mu\nu} = \lambda^{\alpha}_{i}\;\lambda^{i}{}_{\mu\,,\,\nu} \quad (14.6)$$

which are exactly the same as (13.1).

Consequently, from the definitions (6.1), (6,4) we get the identities

$$g_{\underset{++}{\nu\mu}\,;\,\sigma} = 0 \;,\; g^{\underset{++}{\mu\nu}}\,;\,\sigma = 0. \tag{14.7}$$

Thus we can lower and raise indices under the (+) - differentiation sign.

15. Curvature Tensor and Identity :

A curvature tensor $R^{\varepsilon}{}_{\mu\nu\sigma}$ can also be obtained in the case of the non-symmetric affine - connection $\Gamma^{\alpha}_{\mu\nu}$ by parallel displacement of a vector along the boundary of an infinitesimal surface element :

$$R^{\varepsilon}{}_{\mu\upsilon\sigma} = \Gamma^{\varepsilon}{}_{\mu\sigma,\upsilon} - \Gamma^{\varepsilon}{}_{\mu\upsilon,\sigma} + \Gamma^{\alpha}_{\mu\sigma}\;\Gamma^{\varepsilon}{}_{\alpha\upsilon} - \Gamma^{\alpha}{}_{\mu\upsilon}\;\Gamma^{\varepsilon}{}_{\alpha\sigma} \tag{15.1}$$

Since the tetrad-space T_4, when defined by the non-symmetric connection (13.1), admits four linearly independcut fields of (+) — parallel vectors λ^{μ}_{i} (i = 0, 1, 2, 3,) as shown in the above section, it follows [(9) page 19] that.

$$R^{\varepsilon}{}_{\mu\upsilon\sigma} = 0 \tag{15.2}$$

This result, however, could be verified identically if we substitute into the right-hand side of (15.1) for $\Gamma^{\alpha}{}_{\mu\upsilon}$ by their values (13.1). Hence we get the identity :

$$\Gamma^{\varepsilon}{}_{\mu\sigma,\upsilon} - \Gamma^{\varepsilon}{}_{\mu\nu,\sigma} + \Gamma^{\alpha}{}_{\mu\sigma}\;\Gamma^{\varepsilon}{}_{\alpha\upsilon} - \Gamma^{\alpha}{}_{\mu\upsilon}\;\Gamma^{\varepsilon}{}_{\alpha\sigma} \equiv 0. \tag{15.3}$$

This identity can be put into the form [(5), equation (9)]

$$\left(\Lambda^{\varepsilon}{}_{\nu\sigma\,;\,\underset{+}{\mu}} + \Lambda^{\varepsilon}{}_{\sigma\mu\,;\,\underset{+}{\nu}} + \Lambda^{\varepsilon}{}_{\mu\nu\,;\,\underset{+}{\sigma}} \right)$$

$$+ \left(\Lambda^{\alpha}{}_{\nu\sigma}\;\Lambda^{\varepsilon}{}_{\mu\alpha} + \Lambda^{\alpha}{}_{\sigma\mu}\,\Lambda^{\varepsilon}{}_{\upsilon\alpha} + \Lambda^{\alpha}{}_{\mu\upsilon}\,\Lambda^{\varepsilon}{}_{\sigma\alpha} \right) \equiv 0, \tag{15.4}$$

where $\Lambda^{\alpha}{}_{\mu\upsilon}$ is Einstein's skew tensor (13.3) and

$$\Lambda^{\varepsilon}{}_{\nu\sigma\,;\,\underset{+}{\mu}} \equiv \Lambda^{\varepsilon}_{+}{}_{\underset{+}{\nu}\,\underset{+}{\sigma}\,;\,\mu} \tag{15.5}$$

Noting that

$$\left.\begin{aligned} \Lambda^{\alpha}{}_{\mu\alpha} &= C_{\mu} \\ \text{and} \qquad \Lambda^{\alpha}{}_{\alpha\mu} &= -C_{\mu} \end{aligned}\right\} \tag{15.6}$$

and contracting (15.4) for ε and μ, we get the identity

$$\Lambda^{\varepsilon}{}_{\upsilon\sigma\,;\,\underset{+}{\varepsilon}} + C_{\underset{+}{\sigma}\,;\,\upsilon} - C_{\underset{+}{\upsilon}\,;\,\sigma} - C_{\alpha}\,\Lambda^{\alpha}{}_{\upsilon\sigma} \equiv 0. \tag{15.7}$$

We shall show that this is the world-from of the identity (12.3). Apart from the (+) sign characterizing the type of differentiation involved, the identity (15.7) is the same as that given by Einstein [(4) equation (3a)] with his vector $\phi_{\mu} \equiv C_{\mu}$.

16. World-Tensors of The Second Order :

Contracting the curvature tensor (15.1) for ε, μ we get

$$R^{\varepsilon}{}_{\varepsilon\upsilon\sigma} = \Gamma^{\varepsilon}{}_{\varepsilon\sigma,\upsilon} - \Gamma^{\varepsilon}{}_{\varepsilon\upsilon,\sigma} \tag{16.1}$$

But from relations (15.2), we have

$$\Gamma^{\varepsilon}{}_{\varepsilon\sigma} = \left\{ {\varepsilon \atop \varepsilon\sigma} \right\} = \frac{\partial \log \sqrt{g}}{\partial x^{\sigma}} \tag{16.2}$$

in virtue of (10.5) with $g = |g_{\mu\nu}|$. Therefore,

$$R^{\varepsilon}{}_{\varepsilon\upsilon\sigma} = \frac{\partial^2 \log \sqrt{g}}{\partial x^{\upsilon}\,\partial x^{\sigma}} - \frac{\partial^2 \log \sqrt{g}}{\partial x^{\sigma}\,\partial x^{\upsilon}} = 0, \tag{16.3}$$

in conformity with (15.2) and not giving rise to any tensor.

Contracting (15.1) for ε,σ we get after some re-arrangements of terms:

$$R^{\varepsilon}{}_{\mu\upsilon\varepsilon} = G_{\mu\nu} + C_{\mu\,;\underset{+}{\nu}} + C_{\alpha}\,\gamma^{\alpha}{}_{\mu\upsilon} - \gamma^{\varepsilon}{}_{\mu\nu\,;\underset{+}{\varepsilon}}$$

$$- \gamma^{\varepsilon}{}_{\mu\alpha}\,\gamma^{\alpha}{}_{\upsilon\varepsilon}\,, \qquad (16.4)$$

where $G_{\mu\nu}$ is the Ricci tensor corresponding to the symmetric connection $\left\{ {\alpha \atop \mu\upsilon} \right\}$ defined by (8.1). Hence, we get the following second order tensors :

Symmetric tensors : $G_{\mu\nu}$, $\gamma^{\varepsilon}{}_{\mu\alpha}\ \gamma^{\alpha}{}_{\nu\varepsilon}$,

non-Symmetric tensors : $C_{\mu\,;\underset{+}{\nu}}$, $C_{\alpha}\,\gamma^{\alpha}{}_{\mu\nu}$, $\gamma^{\varepsilon}{}_{\mu\upsilon\,;\underset{+}{\varepsilon}}$

By analogy with the last two tensors and with the second one, we also get:

Skew-symmetric : $C_{\alpha}\ \gamma_{\mu\upsilon}{}^{\alpha}$, $\gamma_{\mu\upsilon}{}^{\varepsilon}\ ;_{\underset{+}{\varepsilon}}$

non-symmetric : $\gamma^{\alpha}{}_{\mu\varepsilon}\ \gamma^{\varepsilon}{}_{\alpha\upsilon}$

Symmetric : $\gamma^{\alpha}{}_{\varepsilon\mu}\ \gamma^{\varepsilon}{}_{\alpha\upsilon}$, $C_{\mu}\ C_{\nu}$

Hence splitting the non-symmetric tensors into their symmetric and skew-symmetric parts, we get the set of world-tensors shown in table II.

With somewhat complicated algebra, we can show that the mesh-tensors of Table I will give rise to the corresponding world-tensors of table II. For detailed proofs see [(16) pp. 60-65.]

Here again, apart from the symmetric tensor $g_{\mu\upsilon}$, we have seven symmetric and five skew-symmetric independent tensors.

TABLE (II)

World Tensors (1)

Skew tensors	Symmetric tensors
$\xi_{\mu\upsilon} = \gamma_{\mu\upsilon}{}^{\varepsilon}{}_{;\underset{+}{\varepsilon}}$	
$\zeta_{\mu\upsilon} = C_{\alpha}\ \gamma_{\mu\upsilon}{}^{\alpha}$	
$\eta_{\mu\upsilon} = C_{\alpha}\ \Lambda^{\alpha}{}_{\mu\upsilon}$	$\phi_{\mu\nu} = C_{\alpha}\ \Delta^{\alpha}{}_{\mu\upsilon}$
$\chi_{\mu\upsilon} = \Lambda^{\varepsilon}{}_{\mu\upsilon}{}_{;\underset{+}{\varepsilon}}$	$\psi_{\mu\upsilon} = \Delta^{\varepsilon}{}_{\mu\upsilon}{}_{;\underset{+}{\varepsilon}}$
$\mathcal{E}_{\mu\upsilon} = C_{\underset{+}{\mu}}{}_{;\upsilon} - C_{\underset{+}{\upsilon}}{}_{;\mu}$	$\theta_{\mu\upsilon} = C_{\underset{+}{\mu}}{}_{;\upsilon} + C_{\underset{+}{\upsilon}}{}_{;\mu}$
$K_{\mu\upsilon} = \gamma^{\alpha}{}_{\mu\varepsilon}\ \gamma^{\varepsilon}{}_{\alpha\upsilon} - \gamma_{\ \upsilon\varepsilon}\ \gamma^{\varepsilon}{}_{\alpha\mu}$	$\tilde{\omega}_{\mu\upsilon} = \gamma^{\alpha}{}_{\mu\varepsilon}\ \gamma^{\varepsilon}{}_{\alpha\upsilon} + \gamma^{\alpha}{}_{\nu\varepsilon}\ \gamma^{\varepsilon}{}_{\alpha\mu}$
	$\omega_{\mu\upsilon} = \gamma^{\varepsilon}{}_{\mu\alpha}\ \gamma^{\alpha}{}_{\upsilon\varepsilon}$
	$\sigma_{\mu\upsilon} = \gamma^{\varepsilon}{}_{\alpha\mu}\ \gamma^{\alpha}{}_{\varepsilon\nu}$
	$\alpha_{\mu\upsilon} = C_{\mu}\ C_{\upsilon}$
	$G_{\mu\nu} = \frac{1}{2}(\psi_{\mu\upsilon} - \phi_{\mu\upsilon} - \theta_{\mu\upsilon}) + \omega_{\mu\upsilon}$
Identity: $\eta_{\mu\upsilon} + \mathcal{E}_{\mu\upsilon} - \chi_{\mu\upsilon} \equiv 0.$	

It may be convenient sometimes, for physical reasons, to consider only second order tensors derived from the curvature tensor by contraction. In other words, it may be required to reduce the number of tensors to be considered to a minimum. If this is the case, we can put the contracted curvature tensor (16.4) into the form:

$$R^{\varepsilon}{}_{\mu\upsilon\varepsilon} = G_{\mu\nu} + \underset{+}{C_{\mu}}{}_{;\upsilon} - \underset{++}{\gamma^{\varepsilon}_{-\mu\upsilon}}{}_{;\varepsilon} - \gamma^{\varepsilon}{}_{\mu\alpha}\gamma^{\alpha}{}_{\upsilon\varepsilon} \tag{16.5}$$

Considering the symmetic and skew parts of the second and third members on the right-hand side of (16.5) . we get the following reduced- list.

TABLE III

World tensors (2) - (Reduced list)

Skew tensors	Symmetric tensors
$\varepsilon_{\mu\nu} = \underset{+}{C_{\mu}}{}_{;\nu} - \underset{+}{C_{\nu}}{}_{;\mu}$	$\theta_{\mu\upsilon} = \underset{+}{C_{\mu}}{}_{;\nu} + \underset{+}{C_{\upsilon}}{}_{;\mu}$
${}^{*}\chi_{\mu\nu} = \underset{++}{\Lambda^{\varepsilon}_{-\mu\nu}}{}_{;\varepsilon}$	${}^{*}\psi_{\mu\nu} = \underset{++}{\Delta^{\varepsilon}_{-\mu\nu}}{}_{;\varepsilon}$
	$\omega_{\mu\nu} = \gamma^{\varepsilon}{}_{\mu\alpha}\gamma^{\alpha}{}_{\nu\varepsilon}$
	$G_{\mu\nu} = \frac{1}{2}\left({}^{*}\Psi_{\mu\nu} - \theta_{\mu\nu}\right) + \omega_{\mu\nu}$
	$g_{\mu\nu} = \lambda^{\mu}_{i}\lambda^{i}_{\nu}$
Identity :	${}^{*}\chi_{\mu\nu} - \varepsilon_{\mu\nu} \equiv 0.$

This shows that, confining ourselves to tensors derived only by contracting the curvature tensor, we get, by a special re-arrangement of terms, three independent symmetric tensors (apart from the fundamental tensor $g_{\mu\upsilon}$) and two identical skew tensors.

We also note here that

$$^{*}\chi_{\mu\nu} = \chi_{\mu\nu} - \eta_{\mu\nu} , \tag{16.6}$$

and

$$^{*}\psi_{\mu\nu} = \psi_{\mu\nu} - \phi_{\mu\nu} \tag{16.7}$$

relating the new tensors of table III to those of table II.

17. Ceneralized Coefficients of Rotation :

Considering the mesh-tensor associated with Einstein's tensor(13.3), we get:

$$\begin{aligned}
\Lambda_{ihk} &= \Lambda^{\alpha}{}_{\mu\nu}\, \lambda_{i\alpha}\, \lambda^{\mu}_{h}\, \lambda^{\nu}_{k} \\
&= (\gamma^{\alpha}{}_{\mu\nu} - \gamma^{\alpha}{}_{\nu\mu})\, \lambda_{i\alpha}\, \lambda^{\mu}_{h}\, \lambda^{\nu}_{k} \\
&= \gamma_{ihk} - \gamma_{ikh} && (17.1) \\
&= (\lambda_{i\mu\nu} - \lambda_{i\nu\mu})\, \lambda^{\nu}_{k}\, \lambda^{\mu}_{h} && (17.2)
\end{aligned}$$

But

$$\begin{aligned}
\lambda_{i\underline{\mu};\nu} &= \lambda_{i\mu,\nu} - \Gamma^{\alpha}{}_{\nu\mu}\, \lambda_{i\alpha} \\
&= \lambda_{i\mu,\nu} - \lambda^{\alpha}_{h}\, \lambda_{i\alpha}\, \lambda^{h}{}_{\nu,\mu} \\
&= \lambda_{i\mu,\nu} - \lambda_{i\nu,\mu} \\
&= \lambda_{i\mu\nu} - \lambda_{i\nu\mu} && (17.3)
\end{aligned}$$

Hence

$$\Lambda_{ihk} = \lambda_{i\underline{\mu};\nu}\, \lambda^{\mu}_{h}\, \lambda^{\nu}_{k} \tag{17.4}$$

The invariants Λ_{ihk} may be considered as generalization of Ricci's coefficients of rotation γ_{ihk} .

From (17.1) we note that Λ_{ihk} is skew-symmetric in h, k, while γ_{ihk} is skew in i,h. Taking $i = k$ in (17.1), we get.

$$\Lambda_{ihi} = \gamma_{ihi} \tag{17.5}$$

Hence

$$C_i = \gamma_{hi}{}^{h} = \Lambda_{hi}{}^{h} \tag{17.6}$$

We can also get from (17.1) directly the two relations

$$\gamma_{hik} + \gamma_{hki} = \Lambda_{ikh} + \Lambda_{kih} \tag{17.7}$$

and

$$2\,\gamma_{ikh} = (\Lambda_{ikh} - \Lambda_{kih}) + \Lambda_{hki} \tag{17.8}$$

Relations (17.1), (17.5 - 8) show that we can obtain the same set of mesh-tensors given in Table I by using the non-symmetric connection as well as by using the symmetric one.

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SCATTERING INTENSITY OF POSITRONIUM FORMATION IN HELIUM

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1. Introduction

Since the experimental detection of positronium by Deutsch (1951), a small amount of work has been done in this field. However, the cross section of positronium formation in hydrogen has been calculated by Massey and Mohr (1954) using the Born approximation. They obtained a maximum value of πa_0^2 for an incident positron energy 13.5 e.v. The cross section of positronium formation in helium has been calculated using the same approximation by Massey and Moussa (1961). The maximum cross section has been found to be $0.4\ \pi a_0^2$ for an incident energy 27 e.v. Teutsch and Hughes (1956) calculated the threshold cross section of positronium formation in helium.

It is the purpose of this paper to calculate the scattering intensity for positronium formation in helium as a function of the scattering angle.

2. General Formulation

When a positron is incident on a helium atom, it may pick one of the electrons, and the two particles get bound together to form a hydrogen-like atom, and the helium atom becomes ionized. Such a process is a rearrangement collision.

The positronium is formed in a para-state (singlet) or in an ortho-state (triplet) according as the spin of the two particles are prallel or anti-parallel. The ratio of para to ortho-states is 1:3.

The wave equation representing this system is

$$\left[- \frac{h^2}{8\pi^2 m} \left(\nabla_1^2 + \nabla_2^2 + \nabla_3^2\right) + e^2 \left(\frac{2}{r_1} - \frac{2}{r_2} - \frac{2}{r_3} + \frac{1}{r_{23}} - \frac{1}{r_{12}} - \frac{1}{r_{13}} \right) - E \right] \Psi = 0 \,, \qquad (1)$$

where r_1, r_2, and r_3 are the position vectors of the positron, and the two electrons relative to the nucleus respectively, and E is given by

$$E = E_0 + \frac{h^2 k_0^2}{8\pi^2 m} \,,$$

where E_0 is the energy of the ground state helium atom, m the mass of an electron or a positron, and k_0 is the wave number of the incident positron. The collision is discribed by

$$e^+ + He \longrightarrow He^+ + (e^+ e^-) \,,$$

where e^+, $(e^+ e^-)$, and He^+ represent the positron, positronium, and the ionized helium atom respectively.

The wave function Ψ is taken to be consistent with Pauli Principle in the form

$$\Psi = \psi_0 (r_2, r_3) \; F_0 (r_1) \; \chi_1 (1,23) + \phi_0 (r_3) \; \varphi (r_{12}) \Big[G^P (S_{12}) \; \chi_1 (3,12) + G^0 (S_{12}) \; \chi_2(3,12) \Big] + \phi_0 (r_2) \; \omega(r_{13}) \times \Big[G^P (S_{13}) \; \chi_1 (2,31) - G^0 (S_{13}) \; \chi_2 (2,31) \Big] \; \ldots\ldots\ldots \; (2)$$

where

$$S_{12} = \tfrac{1}{2} \; (r_1 + r_2) \;, \quad r_{12} = r_1 - r_2 \; \ldots\ldots\ldots\ldots\ldots\ldots \; (3)$$

The spin functions χ_1 and χ_2 are given by

$$\chi_1 (1.23) = \frac{1}{\sqrt{2}} \; (\alpha_2 \beta_3 - \alpha_3 \beta_2) \; \alpha_1$$

$$\chi_2\,(3,12) = \frac{1}{\sqrt{6}}\,[(\alpha_1\,\beta_2 + \alpha_2\,\beta_1)\,\alpha_3 - 2\,\alpha_1\,\alpha_2\,\beta_3]\,;$$

ψ_0 and ϕ_0 are the wave functions for the ground states of neutral and ionized helium respectively, ω that for the ground state of positronium, $G^P\,(S_{12})$ being the outgoing wave function of para-positronium formed by electron 2. For ψ_0 we use the simple variational form

$$\psi_0 = \frac{Z^3}{\pi}\,\exp.\,[-Z\,(r_2 + r_3)]\,,$$

and take for E_0 the corresponding value $-Z^2$.

The wave equation will reduce, using the orthogonal properties of the different functions included, to the integro-differential equation

$$\left(\nabla_1^2 + k_0^2 - \frac{2}{r_1}\right) F_0 - 2\iint \psi_0^2\,(r_2, r_3)$$

$$\times\left[\frac{Z-2}{r_2} + \frac{Z-2}{r_3} + \frac{1}{r_{23}} - \frac{1}{r_{12}} - \frac{1}{r_{13}}\right] dr_2\,dr_3$$

$$= \tfrac{1}{2}\iint \psi_0\,(r_2, r_3)\left[\nabla^2_{S_{12}} + K^2 + \frac{8}{r_1} - \frac{8}{r_2} + \frac{4}{r_{23}} - \frac{4}{r_{13}}\right]$$

$$\times\{\,G^P\,(S_{12}) + \sqrt{3}\;G^0\,(S_{12})\,\}\,\omega\,(r_{12})\,\phi_0\,(r_3)\,dr_2\,dr_3 \qquad (4)$$

The solution of this equation should have the asymptotic forms

$$F_0\,(r) \sim e^{ik_0 z} + f_0\,(\theta,\phi)\,\frac{e^{iK_0 r}}{r}$$

$$G^0\,(S) \sim g^0\,(\theta)\,\frac{1}{s}\,e^{iKs}$$

$$G^P\,(S) \sim g^P\,(\theta)\,\frac{1}{s}\,e^{iks}\,,$$

where $K^2 = 4\,E + 9$.

Applying the Born approximation to equation (4),, we obtain

$$g^0(\theta) = \frac{\sqrt{3}Z^3}{2\pi^3} \int\int\int \left\{ \frac{2}{r_1} + (Z-2)\left(\frac{1}{r_2} + \frac{1}{r_3}\right) + \frac{1}{r_{23}} - \frac{1}{r_{12}} - \frac{1}{r_{13}} \right\}$$

$$\times \exp.\left[-Zr_2 - (Z+2)\, r_3 - \tfrac{1}{2}\, r_{12} + i\,(\mathbf{k}_0 .\, \mathbf{r}_1 + \mathbf{K}.\, \mathbf{S}_{12})\right] \mathrm{d}\mathbf{r}_3\, \mathrm{d}\mathbf{r}_{12}\, \mathrm{d}\mathbf{S}_{12}\,, \qquad (5)$$

where $\mathbf{K}$ is the wave vector of the relative motion of positronium and the helium atom after the impact, and θ is the angle between $\mathbf{K}$ and $\mathbf{K}_0$. Integrating the above equation over $\mathbf{dr}_3$, and changing the variables to $\mathbf{P}_1$ and $\mathbf{P}_2$ given by

$$\mathbf{P}_1 = -\,\mathbf{r}_{12} \quad , \quad \mathbf{P}_2 = -\,\mathbf{r}_2,$$

we find

$$g^0(\theta) = \frac{2\sqrt{3}\, Z^3}{\pi^2 (Z+2)^3} \left[H(\theta) - J(\theta) \right]$$

where

$$H(\theta) = \left\{ (4 - Z^2)\, L_1 + 2\, L_2 - 2\,(Z-1)\, L_3 + (Z+2) \times L_4 + 2\, L_5 \right\},$$

$$J(\theta) = \left\{ 2\, L_6 + 2\, L_7 + (Z+2)\, L_8 \right\},$$

where

$$L_t = \int\int \alpha_t \exp.\left[-\tfrac{1}{2}\, P_1 - ZP_2 + \mathbf{i}(\mathbf{k}_1 .\, \mathbf{P}_1 - \mathbf{k}_2 .\, \mathbf{P}_2) \right] \mathrm{d}\,\mathbf{P}_1\, \mathrm{d}\,\mathbf{P}_2\,, \qquad \ldots. \ (6)$$

$$\alpha_1 = 1,\ \alpha_2 = P_1^{-1}\,,\ \alpha_3 = P_2^{-1}\ \alpha_4 = \exp.\left\{ -(Z+2)\, P_2 \right\}$$

$$\alpha_5 = P_2^{-1} .\ \exp.\left\{ -(Z+2)\, P_2 \right\},\ \alpha_6 = (|\,\mathbf{P}_1 + \mathbf{P}_2\,|)^{-1}\,,$$

$$\alpha_7 = \exp.\left\{ -(Z+2)\, |\,\mathbf{P}_1 + \mathbf{P}_2\,| \right\} / |\,\mathbf{P}_1 + \mathbf{P}_2\,|$$

$$\alpha_8 = \exp.\left\{ -(Z+2)\, |\,\mathbf{P}_1 + \mathbf{P}_2\,| \right\}$$

and where $\mathbf{k}_1 = \mathbf{k}_0 - \tfrac{1}{2}\,\mathbf{K}$, $\mathbf{k}_2 = \mathbf{K} - \mathbf{k}_0$.

The scattering intensity I (θ) is given by

$$I(\theta) = \frac{v_f}{v_i} \left| g(\theta) \right|^2,$$

where v_f and v_i are the final and initial velocities of positronium and positron respectively. The cross section Q is calculated using the formula

$$Q = \pi \frac{K}{k_0} \int_0^{\pi} \left| g(\theta) \right|^2 \sin\theta \, d\theta.$$

The integrals (6) were calculated for incident positron energy 19.5, 26.5, 39.1, 54.2, 84.6, and 121.9 e. v. corresponding to values of $k_0 = 1.2, 1.4, 1.7, 2.0, 2.5$, and 3.00 respectively. For K^2 to be > 0, k_0^2 should be > 1.195. This value corresponds to the threshold energy for positronium formation in helium which is 16.2 e.v.

3. Results and Discussions

The results of H (θ) and J (θ) are shown in figs. 1, 2, and 3 for incident positron energy 26.5, 54.2, and 121.9 e.v. respectively. The scattering intensity I (θ) is shown in fig. 4 for the three other values of incident energy : 19.5, 39.1, and 84.6 e. v. given in arbitrary units. On the other hand, the following table shows the scattering intensity I (θ) for positronium formation in helium in units of $3\,(4\,Z/Z+2)^6 \times \alpha^2_0$, and as a function of θ. The interval of θ was taken 7.5°.

Table

Scattering Intensity I (θ) for Positronium Formation in Helium

(units of $3\ (4\ Z/Z + 2)^6 a_0^2$)

θ / k_0 =	1.2	1.4	1.7	2.0	2.5	3.0
0°	0.099	1.234	2.445	2.288	1.234	0.538
7.5	0.086	1.040	1.902	1.613	0.828	0.300
15	0.055	0.610	0.840	0.548	0.172	0.048
22.5	0.022	0.227	0.229	0.063	0.005	0
30	0.002	0.034	0.003	0.003	0.011	0.007
37.5	0.003	0.003	0.013	0.046	0.029	0.012
45	0.021	0.048	0.089	0.075	0.033	0.012
60	0.079	0.146	0.133	0.078	0.026	0.008
75	0.129	0.181	0.118	0.060	0.017	0.005
90	0.155	0.172	0.094	0.044	0.012	0.003
105	0.162	0.152	0.075	0.033	0.008	0.002
120	0.160	0.134	0.061	0.026	0.007	0.002
135	0.155	0.119	0.052	0.022	0.005	0.001
150	0.150	0.109	0.047	0.019	0.005	0.001
165	0.147	0.104	0.043	0.018	0.004	0.001
180	0.146	0.102	0.042	0.017	0.004	0.001

The cross section Q of positronium formation in helium are given by Massey and Moussa (1961) which proves that the size of cross section is of the same order as the elastic scattering cross section.

Teutsch and Hughes (1956) defined the cross section Q of positronium formation in gas atoms by

$$Q = \sqrt{2} \frac{v_f}{v_i} Q'$$

They only calculated Q' at the threshold energy for helium, (where Q vanishes), using the Born approximation, and found it to be $5 \pi \alpha_0^2$. The present calculations give the value $1.2 \pi \alpha_0^2$ for Q'_{thr}. We cannot draw any conclusion from this comparison, since these values do not represent any real process.

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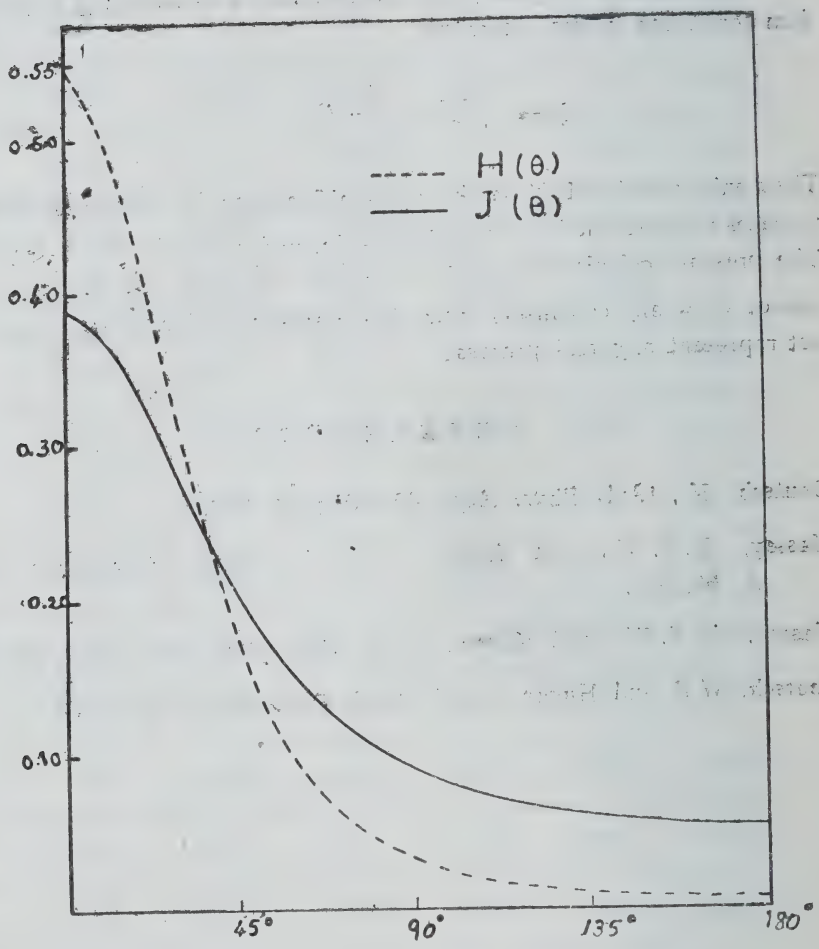

Fig. 1. *Components of scattering amplitude* $H(\theta)$ *and* $J(\theta)$ *in units of* $32\pi^2 a_0$, *for incident energy* 26.5 *e.v.*

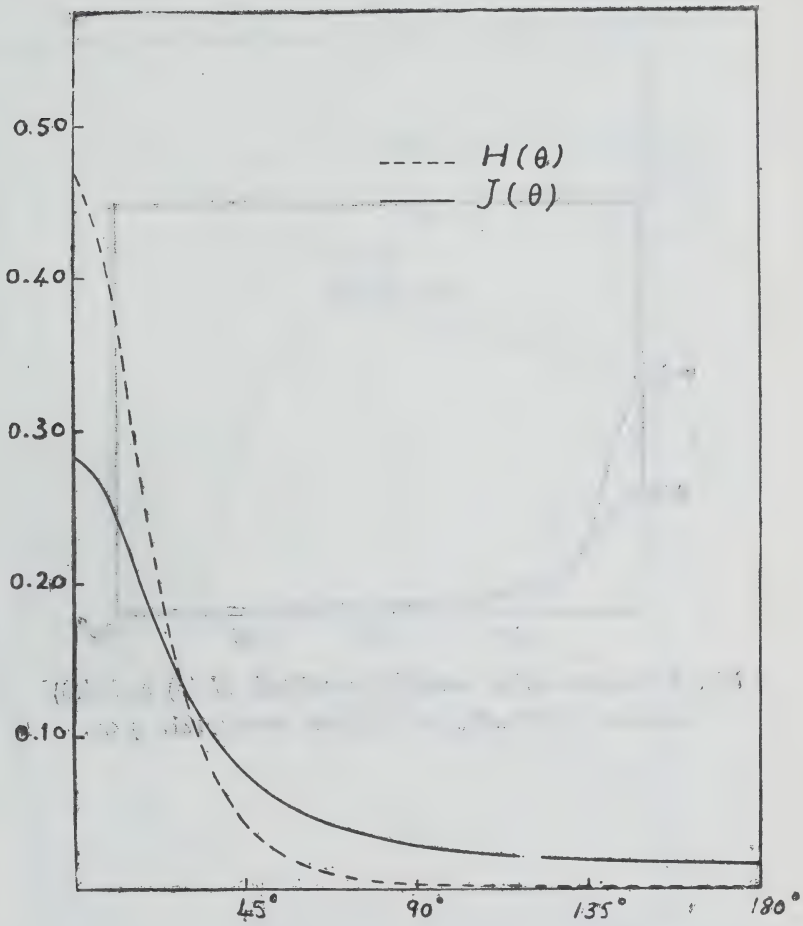

Fig. 2 Components of scattering amplitude $H(\theta)$ & $J(\theta)$ *in units of* $32\pi^2 a_0$, *for incident energy* 54.2 *e.v.*

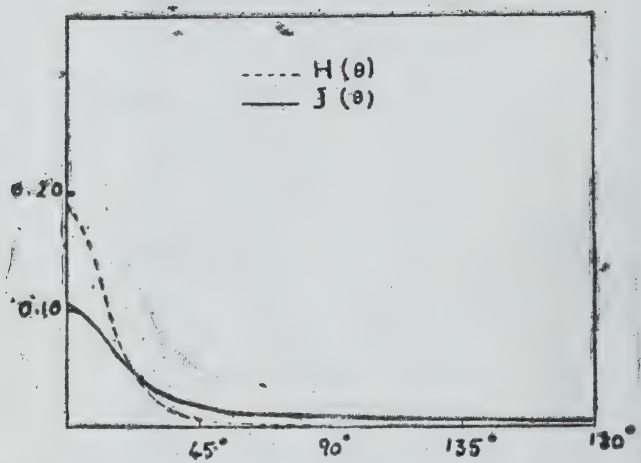

Fig. 3. Components of scattering amplitude H (θ) and J(θ) in units of $32\,\pi^2 a_0$, *for incident energy* 121. *q e.v.*

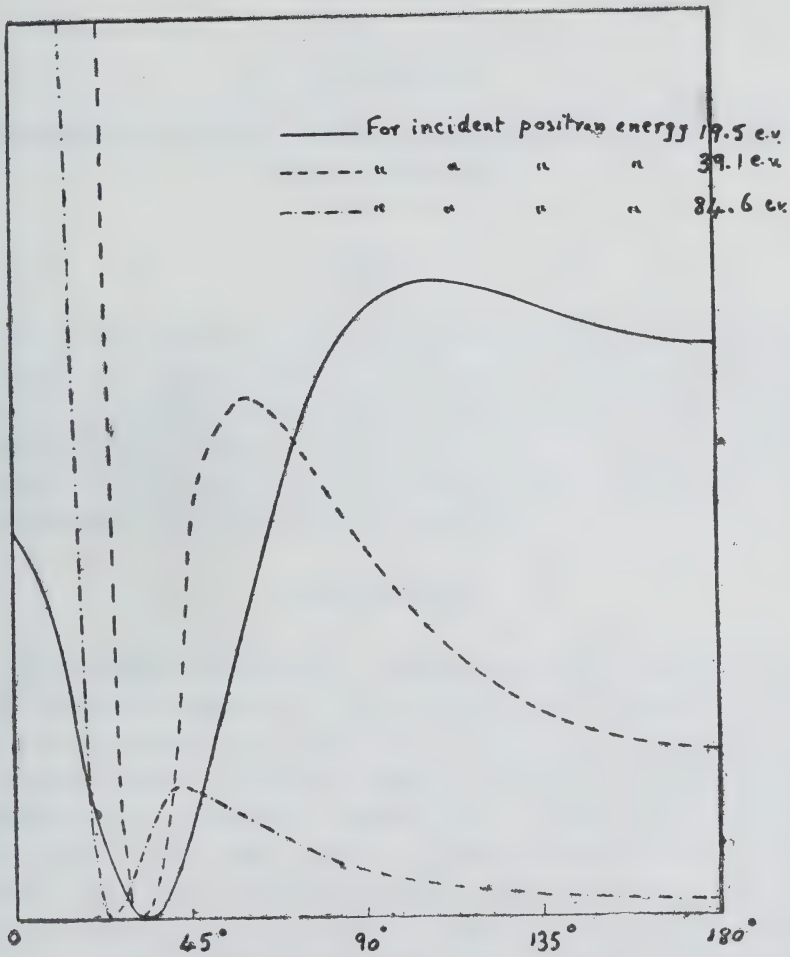

Fig 4. Scattering Intensity I (θ) For Positronium Formation in helium. (in arbitrary units)

THE ELASTIC SCATTERING OF POSITRONS BY HYDROGEN ATOMS (2S — STATE) — VARIATIONAL METHOD TREATMENT

By

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Abstract

The Kohn variational method is applied to the elastic scattering of positrons by hydrogen atoms in the 2s-state. The results are of the same order as those calculated by numerical solution of the integro-differential equation when allowing for (1s – 2s – 2p) coupling. However, when allowing for strong coupling, results are different from those obtained when using variational methods.

1. Introduction

Smith, Miller, and Mumford (1960) have done a programme on a fast electronic computer to solve numerically the integro-differential equations of the problem of elastic and inelastic scattering of positrons by hydrogen atoms for all the s-states. The wave function has been expanded using the method of partial waves When they allowed for strong coulping, the cross section of elastic scattering by 2s-state hydrogen atoms due to incident positron energy 13.6 e.v. was 15.04 πa_0^2 for positrons of zero angular momentum, and when they allowed for (1s- 2s – 2p) coupling this result was reduced to 0.56 πa_0^2 . A review of this problem is given by Burke and smith (1962).

In the present paper the Kohn variational method is applied to the elastic scattering of positrons by hydrogen 2s-state atoms .

Results will be shown to be of the same order as those obtained when allowing for (1s - 2s - 2p) coupling, but much smaller than those obtained using the strong coupling method.

2. Anlaysis of the problem

The wave equation for the system of a positron and an excited hydrogen atom can be written

$$(H - E)\ \Psi = 0, \qquad (1)$$

where

$$H = -\frac{h^2}{8\,m\pi^2}(\nabla_1^2 + \nabla_2^2) - e^2/r_1 + e^2/r_2 - e^2/r_{12}\ ,$$

and where r_1, r_2 are the distances between the atomic electron, the incident positron and the proton respectively, r_{12} being the distance between the positron and the electron, m is the mass of an electron or a positron, and the proton is taken to be the origin in polar coordinates. The energy E is given by

$$E = E_0 + k^2h^2/8\,m\,\pi,^2$$

where E_0 is the binding energy of the excited hydrogen atom which is equal to — 1/8 in atomic units, and k is the wave number of the incident positron.

The variational method used in this problem is due to Kohn. It starts with the integral

$$I = \int\!\!\int \Psi_t^{*}\ (H - E)\ \Psi_t\ dV_1\ dV_2 \qquad (2)$$

where dV_1 and dV_2 are the elements of volume corresponding to coordinates r_1 and r_2 respectively. Ψ_t is a trial wave function which should have the asymptotic form for large r_2 :

$$\Psi_t \sim \psi_{2s}\ (r_1).\ (\sin kr_2 + a \cos kr_2)\ /\ r_2$$

where ψ_{2s} (r_1) is the wave function of the hydrogen atom in the 2s-state. Ψ_t is chosen to include n parameters $p_1, p_2, \ldots p_n$

According to Kohn's method the equations leading to the phase shift η are given by

$$\frac{\partial I}{\partial a} = 4\pi k \tag{3}$$

and

$$\frac{\partial I}{\partial p_r} = 0 \qquad (r = 1,2, \ldots, n) \tag{4}$$

η will then be given by :

$$\eta = \arctan (a - I/4\pi k) \tag{5}$$

and thus, the cross sections are calculated using the formula

$$Q = (4\pi \sin^2 \eta) / k^2 \tag{6}$$

The trial wave function Ψ_t is chosen to be

$$\Psi_t = \psi_{2s}(r_1) F(r_2),$$

where

$$F(r_2) = [\sin kr_2 + \{a + b \exp.(-r_2/a_0)\}\{1 - \exp.(-r_2/a_0)\} \times \cos kr_2] / r_2,$$

b being an adjustable parameter, and

$$\psi_{2s}(r_1) = \{(2 - r_1) \exp.(-r_1/2)\} / 4\sqrt{2\pi}$$

Calculations were carried out for $k = 0.5, 1.0, 1.2, 1.5$, and 2.0, corresponding to incident positron energy 3.4, 13.5, 19.5, 30.4, and 54 e.v. respectively.

3. Results.

The final result of the integral I is given in terms of the parameters a and b in the form

$$I = \alpha a^2 + \beta b^2 + \gamma ab + \lambda a + \mu b + \nu \tag{7}$$

The coefficients α, β, γ, λ, μ, and ν are given for the different values of k in Table I. Applying equations (3), (4), & (5), we obtain the values

of a, b and consequently of I and the phase shift η. These values are shown in Table II. The cross sections of the elastic scattering of positrons by 2s – state hydrogen atoms are calculated using equation (6) and are given in Table III, which also includes the numerical calculation results.

Table I : Values of the coefficients in equation (7) for different values of k.

k	α	β	γ	λ	μ	ν
0.5	2.68549	0.65258	2.04470	3.68840	1.03000	2.56815
1.0	2.34508	0.55117	1.65899	3.72455	1.14236	3.91344
1.2	2.31720	0.50432	1.53079	3.89370	1.09004	4.26758
1.5	2.29659	0.49827	1.48202	4.17596	1.05602	4.70559
2.0	2.28298	0.45905	1.39135	4.95962	0.83620	5.27570

Table II : Values of a, b, I and η.

k	a	b	I (units of π)	η (radians)
0.5	–0.03449	–0.73515	2.09145	–0.82394
1.0	0.90938	–2.40489	6.05207	–0.54309
1.2	1.10794	–2.76220	7.57816	–0.44006
1.5	1.42080	–3.19266	10.25941	–0.28143
2.0	1.71062	–3.42850	14.72675	–0.15400

Table III : Cross sections Q_{2s-2s} of elastic scattering of positrons by hydrogen atoms.

k	E (e. v.)	Q_{2s-2s} Variational Method	Q_{2s-2s} Numerical Calculations (1s-2s-2p) Coupling	Strong Coupling
0.5	3.4	8.616	-	-
1.0	13.6	1.068	0.56	15.04
1.2	19.5	0.504	0.76	5.71
1.5	30.4	0.137	1.29	2.58
2.0	54.0	0.024	0.87	1.11

4. Discussion of Results

Smith, Miller and Mumford (1960) used the method of partial waves to solve the wave equation for this problem. They separated out the motion of positron and the hydrogen atom by expanding the overall wave function for the system in terms of the complete set of eigenfunctions of the hydrogen atom Hamiltonian. The number of terms taken determines the approximation used. Their results are shown in table III. It is clear that the cross sections obtained when using the (1s-2s-2p) coupling are of the same order of magnitude as those obtained when using the variational method. This indicates that the variational method is aplicable for cross sections of states other than ground states. When the strong coupling terms are included, the discrepancy in results is large. One may say that the polarization of the atom which was neglected in the variational method may be responsible for this discrepancy. There are two ways of interpretting the effect of polarization. One way is to introduce the distance between the incident positron and the atomic electron in the trial wave function as was done by Massey and Moussa (1958). The other way is by regarding the polarization effect as due to virtual positronium formation as was done by Moussa (1959). The second way is more effective than the first.

On the other hand the numerical calculations done by Smith et al (1960) for the two methods used give inconsistent results. The authors gave no explanation for these differences.

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STUDIES ON THE TOTAL CHOLESTEROL IN THE PLASMA OF THE DESERT MAMMAL JACULUS JACULUS

by

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INTRODUCTION

Cholesterol is one of the substances which participate in the formation of the cell membranes of the tissues. Its amount is insufficient to form even a monomolecular layer. This fact is in agreement with the unquestioned permeability of the cell membrane to water and water soluble substances. If free cholesterol formed a complete layer, it would be comparable to a waterproof coating due to its hydrophobic character (Mitchell, 1948) . Deuel (1955) reviewed the relationship between atherosclerosis and hypercholesterolemia, in a sense that the deposition of cholesterol on the arterial wall supervenes when the total cholesterol content of the plasma increases above the normal levels. In view of these facts and the fact that excretion of urine depends on the process of diffusion across the cells of glomeruli, it is thought that it might be interesting to determine the total plasma cholesterol content in the desert mammal **Jaculus jaculus** under different experimental conditions and to correlate these findings with the water balance in this animal.

Deuel (1955) reported the average values for the total cholesterol in the blood plasma of different mammals in mg./100 ml. plasma : man (152 ± 24), guinea pig (32 ± 5), albino rat (52 ± 12), rabbit (15 ± 18), cow (110 ± 32), and the cat (93 ± 24).

Cholesterol appears to remain quite constant in the blood throughout the 24 hours period although Mc-Eachern and Gilmour (1932),

noted wide variations in the blood cholesterol values over 5 hours interval. But more recent investigations, supported the fact that alterations in this lipid fraction are insignificant and that the blood level of cholesterol remains largely unaffected by ordinary meals and by the usual activities (Bruger and I. Stomach, 1932 ; and Turner and Steiner, 1939). However, Pfeiffer (1930) recorded that the total cholesterol in blood is increased in summer while in winter it is at a minimal level.

According to the results of Sure and collaborators (1933) the blood cholesterol of fasting rats was found to remain constant while Entenman et al (1940) found that dogs subjected to acute fasting resulted in a decrease in the cholesterol of the blood. In rabbits, blood cholesterol is elevated on fasting (Ellisand and Gardner, 1913. and Shope, 1947.)

MATERIAL AND METHODS

Animals used in the present work are the lesser Egyptian jerboas; **Jaculus jaculus**. Four groups of animals were experimented on ; normal ones, animals fed on dry barley (water content 8 - 10%) for 10 days before experimentation, others fed on soaked barley (water content 45 — 50%) for 10 days. The last group is animals deprived from food for 2 days.

Specimens of **Jaculus jaculus** were killed by severing the blood vessels in the neck region with sharp razor. The oesophagus was left intact to avoid any possible exudation of fluids from the alimentary canal which might mix with the blood during the process of collection. Blood was received in a container in which one mg. of heparin was put as an anticoagulant per one ml. blood (one mg. of this heparin prevents the coagulation of 7.5 ml. cat's blood for 24 hours).

Cholesterol was determined in the plasma by the method of Sackett (1925).

RESULTS

The accompanied table shows that there is a noticable sex

variation concerning the average total cholesterol content of plasma in all normal and dry-fed animals as well as the starved animals in the cold season in a sense that females have higher average contents than the males. On the other hand, in animals fed on soaked barley ; females have lower values than males, while in the case of starved animals in the hot season, the difference is insignificant.

The season was found to have a prononuced effect on the concentrations of total cholesterol in plasma. The average concentrations are higher in the hot than in the cold season.

The hydration was found to have a significant effect on the plasma cholesterol content for dry-fed and soaked-fed auimals. The data indicate that hydrated specimens have lower plasma cholesterol contents than the dry-fed specimens.

It is clear that the averages of the total plasma cholesterol concentrations for the starved specimens are lower than that of the normal ones, with the exception of males in the hot season,

DISCUSSION

The above mentioned results show that there are sex variations which should be taken into consideration when evaluating the effect of the experimental factors ; which are season, hydration and starvation ; on the total plasma cholesrerol concentration of the desert mammal **Jaculus jaculus.** It could be noticed that specimens under unfavourable water balance conditions namely in the hot season or fed on dry barley, have higher total plasma cholesterol concentration than the corresponding specimens under the comparatively favourable water balance conditions namely in the cold season or fed on soaked barley. These findings are in a good agreement to what was hoped that the total plasma cholesterol concentration should increase under the unfavourable water balance conditions to participate with other factors in decreasing the amount of water lost through micturition. This decrease in the urine formation through the probable effect of cholesterol

is brought about by the probable deposition of cholesterol on the walls of the glomeruli thus decreasing the rate of filtration of the fluids through them. The results of the amounts of urine excreted by **Jaculus jaculus** under these experimental conditions, which will be puplished elsewhere, are in good agreement to the above mentioned findings.

One should be aware of the fact that the decrease in the urine formation in the hot season is due to the increased water loss through the total body surface and the respiratory tract, but at the same time one should not ignore other factors which bring about such decrease in the amount of urine excreted, of which the plasma cholesterol concentration might be taken into consideration especially when the effect of hydration on micturition is considerd.

It is clear that the above mentioned hypothesis could not be applied to the starved animals when compared with the normal ones. This might be due to the fact that the starved animals are not only under a negative water balance, but also under a negative nutritive blance which probably leads to the gradual consumption of cholesterol as a fuel for energy.

SUMMARY

A proposed hypothesis on the probable deposition of cholesterol; due to an increase in its concentration in the plasma, on the walls of the glomeruli as a measure to minimize the rate of filtration of fluids through them was found to be accepted in the specimens of the desert mammal **Jaculus jaculus** experimented on.

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TABLE

Average and ranges of the total cholesterol concentration in the plasma of **Jaculus jaculus** under different experimental condititions

Condition	No of animals	Weight (gm.)		Length (cm)		Atmospheric temp. °C		Cholesterol (mg./100 ml. plasma)	
		Aver.	Ranges	Aver.	Ranges	Aver.	Ranges	Aver.	Ranges
N., H. Femalas,	13	45.4	53.6—30.0	10.4	11.8—8.6	21.2	32.5—25.0	255.50	342.50—132.91
N., C. "	6	54.1	59.2—44.7	11.2	11.5—10.7	14.5	16.2—11.5	196.83	361.69—97.55
N., H. Males	6	43.9	51.8—30.2	10.2	11.0—8.4	26.9	29.0—25.0	188.93	253.40—112.50
N., C "	7	55.0	59.1—49.2	10.9	11.5—10.0	14.4	16.1—11.5	168.46	256.40—95.74
D., H., Females	10	49.5	61.0—36.6	10.7	11.5—10.0	28.1	31.5—25.0	202.54	308.21—112.50
D., C., "	6	59.5	73.1—52.9	11.4	12.0—11.2	14.8	16.7—11.5	167.65	225.30—85.26
D., H., Males	5	38.9	43.0—37.2	10.0	10.6—9.5	27.8	32.8—24.0	138.87	225.59—137.50
D., C., "	8	51.4	59.9—43.4	10.9	11.5—10.5	14.8	15.5—13.4	133.39	203.11—63.95
So., H.; Females	8	44.7	51.7—30.7	11.5	11.3—9.5	27.3	30.5—25.0	142.06	192.50—93.75
So., C., "	7	50.5	56.0—47.5	10.9	11.2—10.6	14.4	17.5—13.0	99.93	132.80—60.68
So., H., Males	8	42.9	53.6—39.0	10.4	11.2—9.5	27.8	33.5—22.4	187.83	212.20—150.00
So., C., "	8	50.6	60.3—47.0	10.9	11.5—10.4	14.5	17.0—12.2	120.39	231.23—52.08
St., H., Females	9	44.1	53.6—34.7	10.5	11.3—9.9	28.3	32.5—24.2	197.03	235.24—92.50
St., C. "	8	52.7	62.1—42.2	11,0	11.5—10.3	14.4	16.2—10.0	179.86	250.00—111.11
St., H., Males	6	38.9	42.2—33.3	10.2	10.8—9.8	28.1	31.2—23.0	198.08	237.78—150.20
St., C., "	5	47.7	52.0—42.7	10.8	11.0—10.7	13.0	15.0—11.0	127.22	201.88—91.46

C. Cold season
H. Hot season
So. Animals fed on soaked barley
D. Animals fed on dry barley.
N. Normal animals.
St. Starved animals.

GLYCOGEN CONTENT OF SOME TISSUES OF THE DESERT MAMMAL JACULUS JACULUS IN RELATION TO ITS BODY WATER ECONOMY

By

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INTRODUCTION

It is well known that the oxidation of 100 gm. carbohydate yields 55.3 ml. water (Harrow, 1946). Thus one might guess that carbohydrates might play a role in the water economy of the desert animals. Since the liver acts as a storehouse for carbohy drate, and having the highest percentage of glycogen, and since the skeletal muscles contain a considerable portion of the total glycogen of the body ; these facts impressed on the present authors to investigate the glycogen content of both the skeletal muscle and the liver, and to correlate it with the water economy of the desert mammal **Jaculus jaculus.**

Best and Taylor (1950) pointed out a general picture for the total glycogen in the body of the dog in which the liver and the muscles contain 38 and 44% respectively of the total glycogen present in the body. Lawrence and McConce (1931) found that the glycogen in the rat's liver reaches 230 mg.%

Wide variations in the glycogen content of the different lobes of the same liver, as well as that of the whole liver in t e different individuals was found out by most of the workers Scheiff (1931) found in dogs, rabbits and turtles, that the different lobes of the same liver as well as the same lobes of the different livers showed considerable

irregular variations in the glycogen content. In addition, the periphery of a lobe was found to be higher in the glycogen content than the interior. Nys et al (1940) recorded heterogenity in the middle lobe of the liver of rabbit. The glycogen content of this lobe was found to be systematically higher than that of the two other lobes, which are usually similar in their glycogen content. Grafflin et al (1940) found in some series of the experiments on guinea pigs that the glycogen content of the liver varies from 3.78 to 9.46%. One view explaining the cause of that variation is that of Folin (1928) who claimed that the use of small samples may lead to erroneous results because they do not represent an average portion of the tissues and stated that the glycogen variations may be due to the presence of large ducts or blood vessels which may be incorporated in certain samples and not in others. For this reason, the author supposed that an average value obtained from several determinations gives a more true picture.

Kerly and Ottoway (1954) demonstrated that the sex of the rates, starvation and the kind of the diet affected the glycogen content of the liver. Slices from fasted rats, previously fed on a diet rich in carbohydrate synthesized more glycogen during incubation in a medium containing glucose than did those from rats previously fed on a high fat or protein diet.

Khalil and Yanni (1956) working on the Egyptian desert reptile Uromastyx, stated that there is a relationship between environmental temperature and the glycogen content of the tissues of Uromastyx, since the maximum deposition of glycogen in the liver occurs in July which is the period of the year having the higher environmental temperature and the highest vital activity of the animals. Moreover, they recorded sex variations in the glycogen content of the liver, the males have higher concentrations (164mg.%) than the females (120 mg.%). They also found that starvation in these animals was followed by an increase in the glycogen content contradicting what is known in mammals in which liver store is depleted under such conditions.

Concerning the skeletal muscles, it is found that not only there is a considerable variations in their glycogen content from species to species, but also different muscles of the same animal do not contain the same amount of glycogen e. g. the gastrocnemius muscle contain 0.6% glycogen in the rat, 1.0 % in the rabbit and 1.8% in the dog (Harrow and Sherwin, 1935). However, the average values of the glycogen recorded in the skeletal muscles of rats were 540 mg.% (Laurence and McConce 1931), 424 mg.% (Evans, 1934) and 232 — 350 mg.% (Sahyun **et al**, 1934).

Khalil and Yanni (1956) recorded very low values for the glycogen in the muscles of Uromastyx as compared with those of mammals. The glycogen content was affected by the environmental temperature, as it was maximum in the period of the year having the highest temperature. The authors found also that during fasting, the glycogen content of the muscles was found to increase from 25.6 to 47 mg.% This unusual rise of glycogen was explained by the authors to be attributed to the great loss in the tissues of the skeletal muscles themselves under such condition.

MATERIAL AND TECHNIQUE

Specimens of the Egyptian desert mammal **Jaculus jaculus** were used in these experiments. Two groups of animals, each of seven males were experimented on; one group was collected in summer and the other group was trapped in winter. Animals were kept from food for 12 hours before the determination of glycogen in the tissues of the animals under examination. Animals were killed by a blow on the head.

Glycogen content of a particular part of the liver and in a particular part of a skeletal muscle in the thigh region was letermined using the method of Carroll **et al** (1956) in which the glycogen was extracted from the tissue by homogenization with 5 % trichloroacetic acid. Glycogen was precipitated by alcohol and then treated with the anthrone reagent which gives results of a high degree of specificity. The colour was measured at 620 mu by Eel photoelectric colorimeter. The tissues were sampled at a particular time of the day.

RESULTS AND DISCUSSION

The data obtained show that the average concentration of glycogen in the skeletal muscle of the thigh region and in the liver of the males of **Jaculus jaculus**, is considerably higher in the hot season than in the cold season. Such an increase in the concentration of glycogen in the hot season might be attributed to the better chances for the animal to get food by night in the hot season (since the animal is nocturnal) than in the cold season. This is because of the comparatively favourable weather of the desert by night in the hot season as compared with that in the cold season which is too cold for the animal to go round and search for food. This increased nutritional condition will lead to the increased concentration of glycogen in both the skeletal muscles and the liver. There is other factor which might contribute in increasing the glycogen concentration in the above mentioned tissues. This factor is the direct effect of temperature on the process of glycogen formation. It is well known that the formation of glycogen from lactic acid is an endothermic reaction and the increasing temperature will, of course, increase the glycogen formation. From the work carried out by Shalaby (1960), on the body temperature of **Jaculus jaculus**, the author recorded a noticeable increase in the body temperature in the hot season. Such a result clearly explains the rise in the concentration of glycogen in the skeletal muscles and the liver.

The increase in the concentration of glycogen of the skeletal muscle in the hot season, gives the impression that the glycogen of the muscles does not participate in supplying the animal, in the hot season, with the needed metabolic water which would result from its oxidation after its transformation to glucose. On the other hand, it seems that the glycogen of the liver takes a share in supplying the animal with such metabolic water in the hot season. Although the concentration of the glycogen in the liver is higher in the hot season than in the cold season, yet the total amount of glycogen in the hot season is lower than that of the cold season, as can be seen from the data, indicating its consumption to yield water. Such an unexpected result of the decreased amount of the total glycogen in the liver is due to the decrease in the weight of the liver observed in the hot season.

SUMMARY

The present work shows that the glycogen content of both the skeletal muscles and the liver of the desert mammal **Jaculus jaculus**, is higher in the hot season than in the cold season. It is found that only the glycogen of the liver is used in excess in the hot season to yield more metabolic water which is greatly needed to the animal by that time of the year, indicating the participation of this glycogen in the body water balance.

ACKNOWLEDGMENT

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The glycogen content of the liver and the skeletal muscle of male **Jaculus jaculus**

Animal			mg. glycogen per 100 gm. fresh skeletal muscle	Weight of fresh liver per animal (gm.)	Weight of fresh liver per 100 gm. body weight (gm.)	Gm. glycogen per 100 gm. fresh liver	Total glycogen in liver per 100 gm. body weight (gm.)
Season	No:	body weight (gm.)					
Hot,	1	50.5	0.5906	1.810	3.584	5.274	18.902
temperature :	2	49.1	—	1.490	3.034	5.115	15.519
39.5-19.5 °C	3	56.1	0.5248	1.028	1.832	5.134	9.405
(in shade)	4	48.1	0.4989	1.079	2.243	5.023	11.266
	5	41.4	0.5002	1.078	2.604	4.986	12.983
	6	56.7	0.4892	1.113	1.963	4.378	8.594
	7	49.0	0.5481	1.110	2.245	5.321	11.945
	Average		0.5251	1.242	2.458	5.032	12.371
Cold,	1	44.2	0.0599	1.686	3.825	2.854	10.916
temperature :	2	49.1	0.1637	1.680	3.421	3.622	12.390
20.5—3.9°C	3	44.7	0.0213	—	—	—	—
(in shade)	4	47.4	0.0928	1.519	3.204	7.545	24.174
	5	45.8	0.0384	1.526	3.332	2.417	9.053
	6	54.8	0.1374	1.591	3.903	4.625	18.051
	Average		0.0856	1:600	3.537	4:212	14.916

COMPARATIVE TOXICITY OF DDT AND MALATHION TO THE AMERICAN COCKROACH, PERIPLANETA AMERICANA

By

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Introduction :-

Malathion has been known to be more toxic than DDT to insects. Therefore, measurements have been made to determine the LD_{50} values in terms of Mg/gm of malathion for the cockroach (**Periplaneta americana** in comparison with DDT.

Metcalf and Kearns (1941) administered measured doses of DDT to the cockroach (**Periplaneta americana**) and reported a lethal dose of the order of 30 mgm of DDT per Kgm, applied to the body surface in emulsion form. David, (1945) has made measurements for the quantity of DDT collected from a spray by flying insects. His figures for maximum median lethal dose are 7 and 10 milligrams / Kgm for the male and female of Aedes aegypti.

Latta, Anderson and Rogers (1945) reported that the approximate amount of surface deposited DDT in oil necessary to kill an **Aedes aegypti** female of average susceptibility is about 0.03 gamma per mosquito ; assuming an average body weight of 1—3 mgm per mosquito; this datum calculates to 10—30 mgm per Kgm. Tobias, Kollros and Savit (1945) found that the approximate LD_{50} for DDT in the cockroach is 5—8 mgm/Kgm when injected in acetone, 10 mgm/Kgm when applied to the body surface in acetone, 18 mgm/Kgm when injected as emulsion and 82 mgm per Kgm when injected in peanut oil. Savit, Kollros and Tobias (1946) found that the approximate LD_{50} for compound γ666

in the cockroach is 4.6 mg per kg when applied to the body surface and 3.4 mg per kg when injected intra-abdominally and found also that Gamma 666 is about twice as toxic as DDT for the cockroach. At present the doses of malathion and DDT required to kill 50% cockroaches, were determined when injected into the abdomen of the chockroach.

Methods and Materials :

Female nymphs of roaches were used. Each roach was weighed at the time of injection and was placed in a Petri dish with filter paper on the bottom ; 4 replicates for each dose were done. Mortality was determined at 24 hours intervals over a 5—day period.

The toxic agents were dissolved in olive oil, were delivered through a 27 - guage hypodermic needle, from a 0.25 cc. tuberculin syringe fitted with a micrometer screw-driven piston. For injection purpose, the needle was made to enter the abdomen beneath a sternite and near its hinge - like point of attachment. Upon withdrawal of a needle so inserted the sternite falls back into place and seals the hole. No leakage has been following such a procedure. Check cockroaches were given equal amounts of olive oil without any toxic agent.

Results :

The obtained data are shown in Tables I and II

Table I — Effect of DDT on cockroaches

% of DDT	No roaches	vol: injected mm^3	DDT Mg/ roach	DDT Mg/grm	% mortality at hrs: indicatee		
					48 hrs.	60 hrs.	120 hrs. (5 days)
0 - control	4	2	0	0	0	0	0
0.0125	4	2	.25	.38	0	0	0
0.025	4	2	.5	.670	0	0	25
0.05	4	2	1	1.426	0	25	25
0.1	4	2	2	3.1	25	25	50
0.2	4	2	4	4.595	50	50	75

Results are graphically expressed in Fig 1.

From the graph the approximate (5 days) LD_{50} for DDT is determined to be 2.6 mg/gm.

Table II — Toxic action of Malathion to cockoaches

% Malathion	No roaches	Vol: injected mm^3	Mala-thion Mg/ roach	Mala-thion Mg/grm	% Mortality at hrs. indicated			
					24hrs.	48hrs.	60hrs:	120 hrs (5 days)
.005	4	2	.125	.31	0	0	25	50
.01	4	2	.25	.41	0	0	25	50
.025	4	2	.5	.71	0	0	25	75
.05	4	2	1	1.53	25	50	50	100

Results are graphically expressed in Fig. 2 From the graph the following values are determined :

Approximate 120 hrs (5 days LD_{50} for malathion 0.35 mg/grm.)

Discussion and Conclusions :-

1. From Table I and II it can be seen that the LD_{50} for malathion applied intra-abdominally to the female cockroach nymphs was 0.35 mg per grm and that of DDT 2.6 mg/grm. These data with DDT were less than that found by Savit et al, 1946, using both sexes of adult cockroach (**P. americâna**) and injection method with DDT which was 3.4 mg/Kg (3.4 Mg / grm). This difference can be explained by that the nymphs can be killed by less doses than adults or in other words, nymphs are more sensitive to DDT than adults.

Summary :-

1. The approximate 5 days LD_{50} for DDT in the female nymphs of cockroach **Periplaneta americana** determined graphically and injected intra-abdominally was 2.6 mg/grm.

2. The approximate 5 days LD_{50} for Malathion in the female nymphs of cockroach (**P. americana**) and injected intra-abdominally was 0.35 Mg/grm.

3. Malathion proved to be about 7 times as toxic as DDT for the cochroach nymphs.

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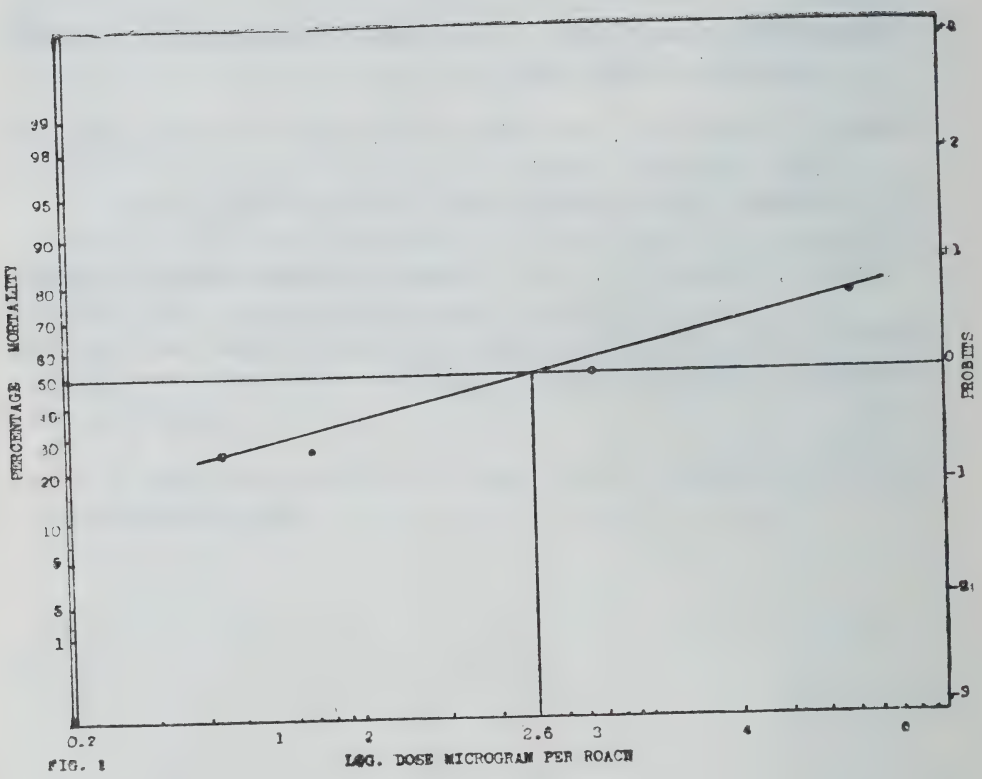
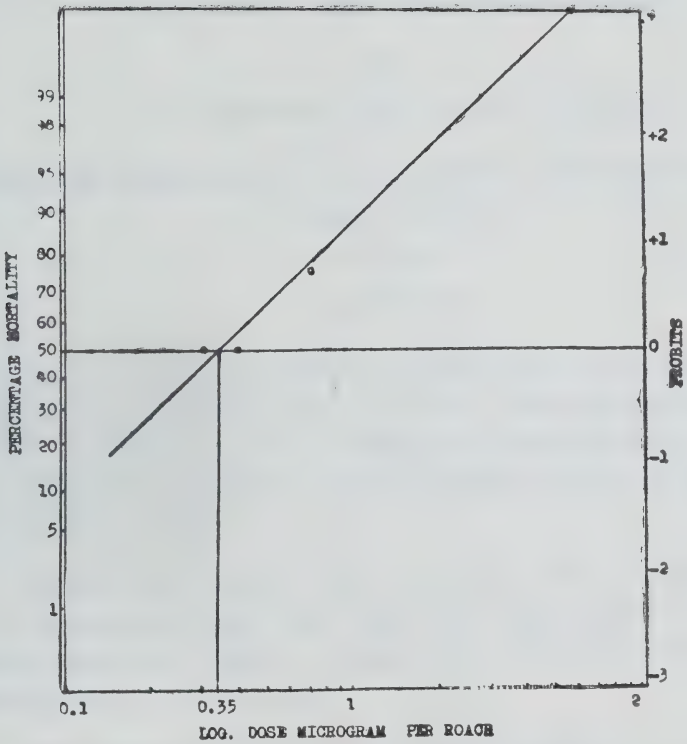

PERCENTAGE MORTALITY
99
98
95
90
80
70
60
50
40
30
20
10
5
3
1
PROBITS
4
2
1
0
-1
-2
-3
0.2
1
2
2.6
3
4
6
LOG. DOSE MICROGRAM PER ROACH

FIG. 1


PERCENTAGE MORTALITY
99
98
95
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80
70
60
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40
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5
1
PROBITS
+3
+2
+1
0
-1
-2
-3
0.1
0.35
1
2
LOG. DOSE MICROGRAM PER ROACH

FFIG. 2

VARIATIONS IN SUSCEPTIBILTY OF THE STORED-PRODUCTS HUMP BEETLE, GIBBIUM PSYLLOIDES CZEMP. (COL. PTINIDAE) TO SOME INSECTICIDES UNDER DIFFERENT TEMPERATURES AND HUMIDITIES

by

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Introduction

Several organic phosphates were found toxic to the khapra beetle, **Trogoderma granarium** the rice - weevil, **Sitophilus granarium** and and the confused flour beetle, **Tribolium confusm**, However, cholorinated hydroearbon insecticides proved ineffective aganist T. **granarium**. (Vincentet al. 1957).

Soliman and Kaschef (1962) studied the effect of some insecticides on **T. afrum**, and fonnd that DDT, BHC and egixane were superior to katelsouse and sulphur. Among plant derivatives Derrisine was found superior to Pyrethrum.

The biological control of the hump beetle, **G. psylloides** was studied by Kaschef (1961). During the present study, the variations in the susceptibility of this beetle ro some insecticides under different different temperatures and humidities were investigated.

Materials and Methods

Adult beetles used in this study were reared on semolina mixed with 8% dried brewer's yeast in 10 x 2 cm. Petri dishes at constant

conditions of temperature (32.5 ± 0.5°C.) and relative humidity (60 ± 5%) .

The experiments were carried out at three temperatures (16°,26° and 40°C.) and four rolative humidities (30°/₀, 50°/₀, 70°/₀ and 90°/₀). Humidity was condtrolled by solutions of potassium hydroxide as described by Buxton aud Mellanby (1934) and by Solomon (1951).

The beetles were exposed to the insecticides on impregnated filter papers in smal Petri dishes of 6 cm. in diameter: In each dish was placed a filter papér of 7 cm. diameter; with its edge edge folded around the sides of the dish. The filter paper was imregnated before introduction into the dish with a half milliletre of the tested insecticide concentration, in a way smilar to that described by Busvi ıe (1957) and Soliman (1962).

Solutions of the insecticides to be tested were prepared at different concentrations in acetone. Half a milliletre of each dilution is carefully pipetted and is evenly distributed on each filter paper. The impregnated paper is then left to dry outside the dish and when completely dry it is fitted in the dish after being carefully labelled. Every dish received 15 beetles and each treatment is replicated two times. In each case checks were run in which the solvent (acetone) only was applied to the insects in equal amounts to those used with the insecticides. Mortialty readings were taken after 24 and 48 hour periods.

The insecticides used here were two phosphorous insecticides (malathion and parthion) of the thiophosphates, two chlorinated hydrocarbons (DDT aud lindane), one of the carbamtes (sevin) and one insecticide of botanical origin (pyrethrum), at concentrations ranging between 0.001°/₀ to 25°/₀ Different concentrations and the number of individuals per dish in each treatment are given in the corresponding tables.

Experimental Results

Results of the present expriments are summarized in Tables I to IV and are also expressed grphically in Figs. 1 to 6.

The results indicate the follwoing:-

1. Based on a cemparison of the 24-hours LD50 values it is noticed that the insecticides used exist in two groups, a less effective one includes parathion, lindane and pyrethrum with values ranging between 0.1 to 8 micrograms and the other more efficient group including malathion, DDT and sevin, with considerably lower LD—50 values.

2. This same grouping applies also for the 48 hours LD50 values.

3. Changes in relative humidites seem to have but little effect on the toxocity of the tested insecticides. There are slight changes in the LD values at different relative humidites, provided the temperature is constant.

4. Variation in temperatures does not affect the relative toxocity of different insecticides. However it affects considerably the toxocity of each of the insecticides.

5. The toxocity of pyrethrum increases with rise of temperature. For pyrethrum, while the 24 hours LD 50 value is about 8 micrograms at both 16° and 26°C, it is less than 1 microgram at 40°C.

6. A similar effect of temperature is noticed for Lindane at lower relative hamidities. At higher humidities variations in toxicity with changes in temperatures are less obvious

Table 1

24 hours LD50 (doses in micrograms/insect)

	Volues at 16°C				at 26°C				at 40°C			
	R.H. 30	50	70	90	30	50	70	90R.H	30	50	70	90%
I. Malathion	666.7	666.7	666.7	333.3	333.7	166.7	166.7	166.7	166.7	41.7	41.7	41.7
II Parathion	8.3	1.7	1.7	1.7	1.7	0.83	0.83	1.7	0.83	0.17	0.83	0.83
III DDT	beyond 2500		—	—	beyond 2500				beyond 2500			
IV Lindane	8.3	8.3	1.7	1.7	8.3	8.3	1.7	0.83	1.7	1.7	1.7	0.83
V Sevin	3333.3	beyond 3333.3										
VI Pyrethrum	16.7	16.7	8.3	8.3	8.3	8.3	8.3	8.3	0.83	0.83	0.83	0.83
	48 hours LD 50											
I Malathion	166.7	166.7	166.7	166.7	166.7	83.3	83.3	41.7	83.3	41.7	16.7	16.7
II parrthion	1.7	0.83	1.7	1.7	0.83	0.17	0.83	0.83	0.83	0.17	0.17	0.17
III DDT	3333.3	1666.7	1666.7	833.3	beyond 2500				beyond 2500			
IV Lindane	1.7	1.7	1.7	1.7	1.7	1.7	0.83	0.83	1.7	0.83	0.83	0.83
V Sevin	833.3	833.3	833.3	833.9	3333.3	3333.3	3333.3	3333.3	3333.3	3333.3	3333.3	3333.3
VI Pyrethrum	8.3	8.3	1.7	1.7	8.3	1.7	1.7	1.7	0.83	0.83	0.83	0.83

Table 3 24 hours LD 95

Insecticide	Values at 16°C				at 26°C				at 40°C.			
	RH.30	50	70	90	30	50	70	90%RH	30	50	70	90%
I Malathion	—	—	—	—	666.7	666.7	666.7	666.7	333.3	166.7	166.7	166.7
II Parathion	8.3	1.7	8.3	8.3	8.3	0.83	1.7	1.7	8.3	0.83	0.83	1.7
III DDT		beyond	4166									
IV Lindane	41.7	41.7	41.7	41.7	41.7	41.7	16.7	16.7	41.7	16.7	16.7	16.7
V Sevin	3333.3	3333.3	Beyond	3333.3	Beyond	3333.3			Beyond	3333.3		
6 Pyrethrum	41.7	41.7	41.7	16.7	16.7	16.7	16.7	16.7	0.83	0.83	8.3	8.3

Table 4 48 hours LD 95

I Malathion	—	—	—	—	333.3	333.3	333.3	333.3	166.7	83.3	83.3	41.7
Parathion	—	1.7	1.7	1.7	1.7	1.7	0.83	0.83	0.83	0.83	0.83	0.83
DDT			Beyond	4166								
Lindane	41.7	41.7	16.7	8.3	16.7	16.7	16.7	8.3	8.3	8.3	8.3	1.7
Sevin		Beyond	3333.3									
Pyrethrum	41.7	41.7	41.7	41.7	16.7	16.7	16.7	16.7	0.83	0.83	0.83	0.83

Discussion of Results and Conclusions

Among the factors which effect the toxicity of insecticides temperature and humidity are the most important.

Results of the present study indicate that:

1. The toxicity of Malathion. Parathion, Lindane and Pyrethrum increased by rise in temperature (having a positive temperature coefficient).

2. On the contrary the toxicity of DDT and Sevin decreased at higher temperatures (negative temperature coefficient). Similar results were previously recorded by several authors (Dustan — 1947, Gaines et al — 1948, 1949, Brown — 1951, Vinsank — 1952 and others).

3. The rise in humidity increased the toxicity of Malathion only at higher temperatures (40^0 C).

4. In case of Parathion the maximum toxicity was approached at 50% R.H.

5. For DDT the toxicity increased by rise in the humidity only at lower temperatures (16^0 C).

6, The toxicity of Sevin and Pyrethrum, however is not affected by changing the relative humidity,

The better kill brought up by DDT at lower temperatures may be due to the change in solubility of this insecticide due to variations in temperature. At higher temperatures it is more soluble in tissues and lipids of the cuticle where it becomes readily stored instead of moving to its site of action

Summary

The susceptibility of **Gibbium psylloides** Czemp. To six insecticides using the contact (pick up) method has been studied. The insecticides used were two phosphorous compounds (malathion and parathion), two chlorinated hydrocarbons (DDT and lindane), one carbamate (sevin) and one plant derivative (pyrethrum). According to the LD 50 values

obtained at 26°C and 50% R.H. the ineecticides used can be arranged in their order of efficiency as follows : parathion, lindane, pyrethrum, malathion, sevin and DDT.

The toxicity of malathion, parathion, lindane and pyrethrum was found to increase by rise in temperature while that of sevin and DDT is reduced when temperature increases

Unlike temperature, relative humidity has no significant effect on the toxicity of most of the used insecticides. The toxicity of malathion and parathion may increase by high humidity especielly at high temperatures. In case of DDT and lindane the increase of toxicity at high humidity especially at low temperatures is more obvious than that obtained with posphorous insecticides. In case of sevin and pyrethrum high humidity seems to have no significant effect on toxicity.

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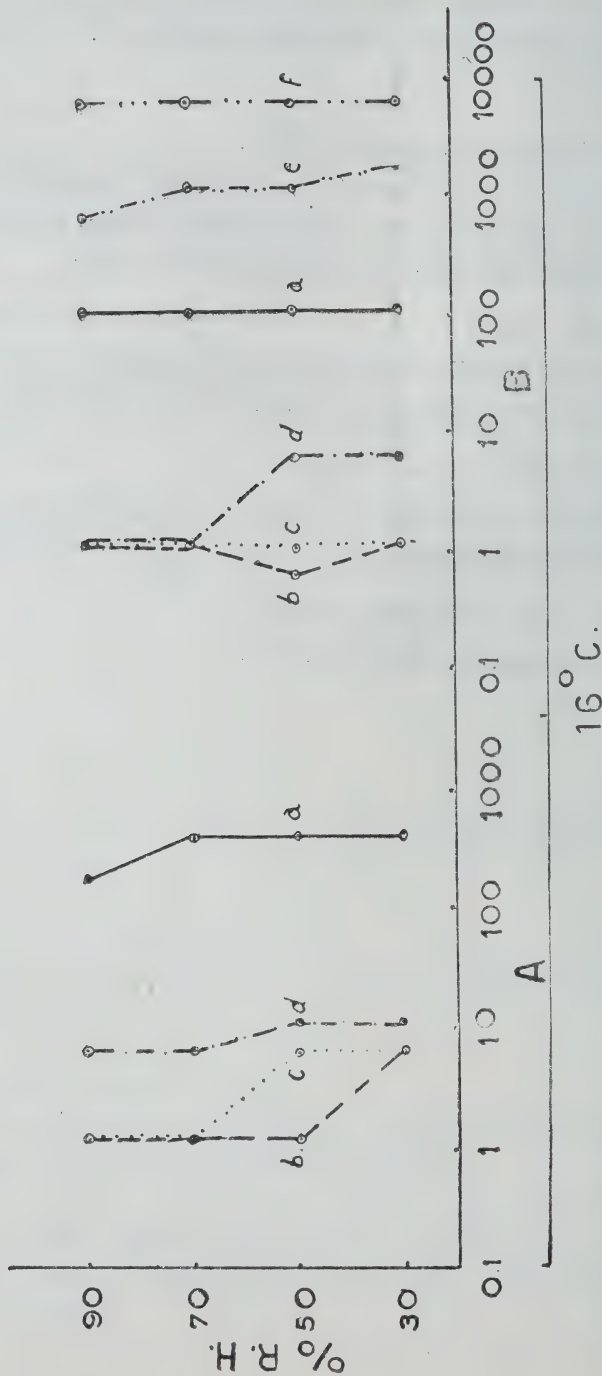
90
70
50
30
% R. H.
0.1
1
10
100
1000
0.1
1
10
100
1000
10000
A
B
a
b
c
d
e
f
16° C.

Fig: 1

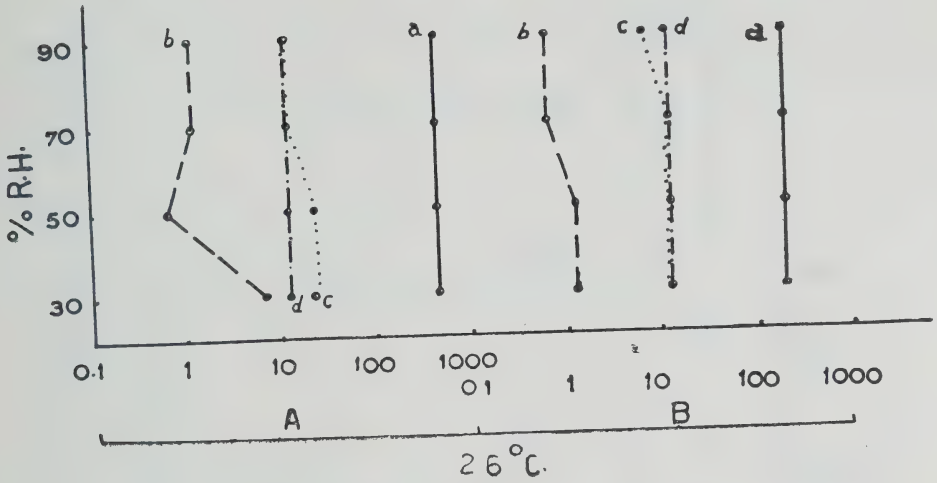
% R.H.
90
70
50
30
b
d
c
a
b
c
d
a
0.1
1
10
100
1000
0.1
1
10
100
1000
A
B
26°C.

Fig. 2

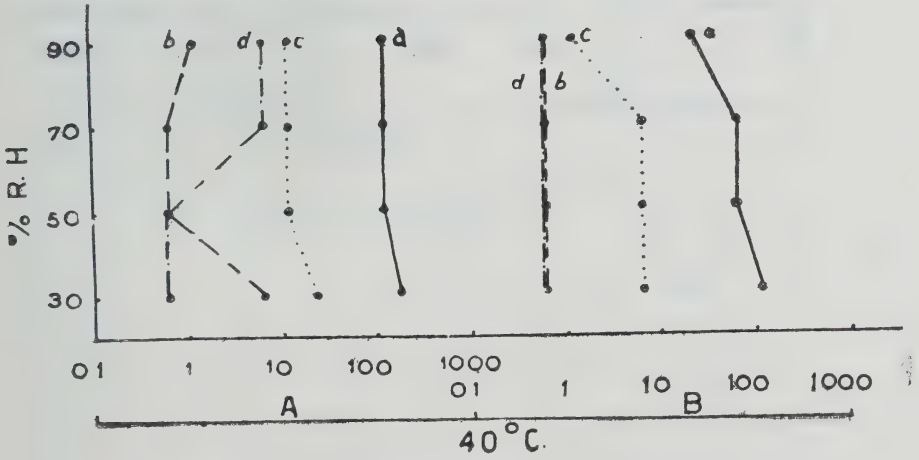
% R.H
90
70
50
30
b
d
c
a
c
d
b
a
0.1
1
10
100
1000
0.1
1
10
100
1000
A
B
40°C.

Fig. 3.

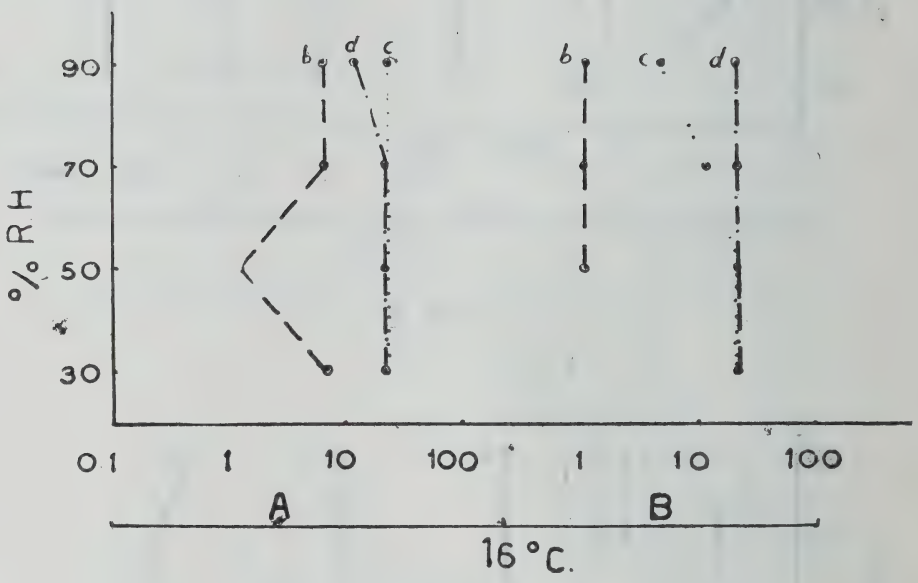

Fig: 4

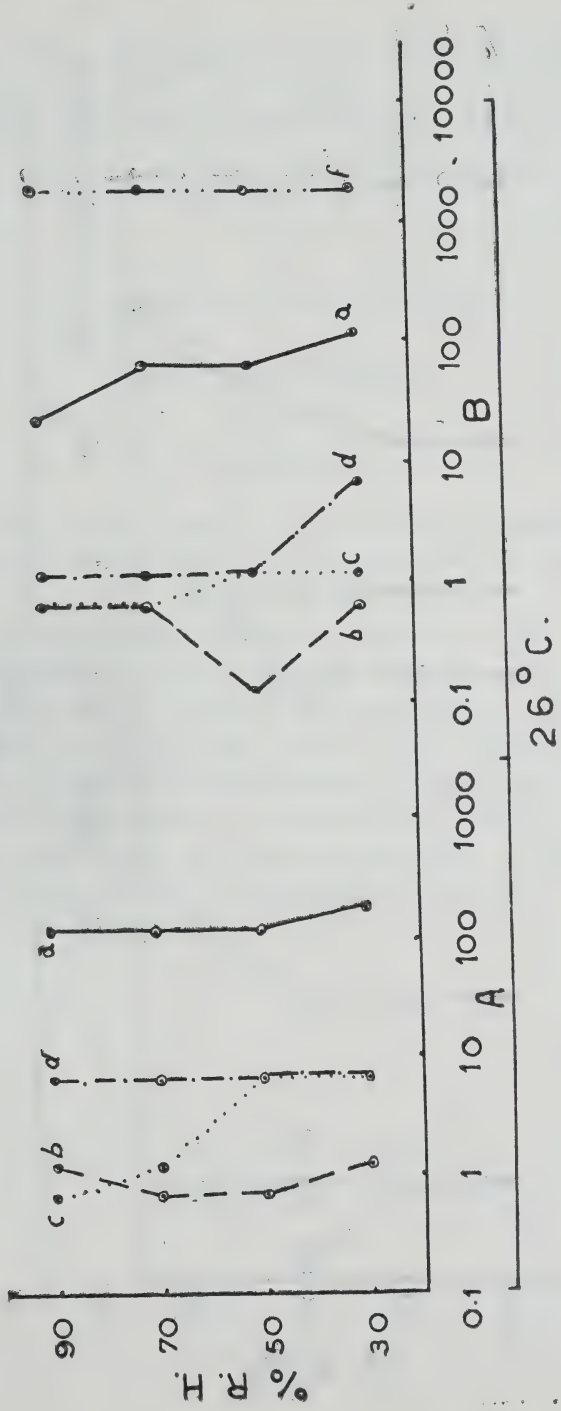
% R. H.
90
70
50
30
0.1
1
10
100
1000
A
0.1
1
10
100
1000
10000
B
26° C.
a
b
c
d
e
f

Fig. 5

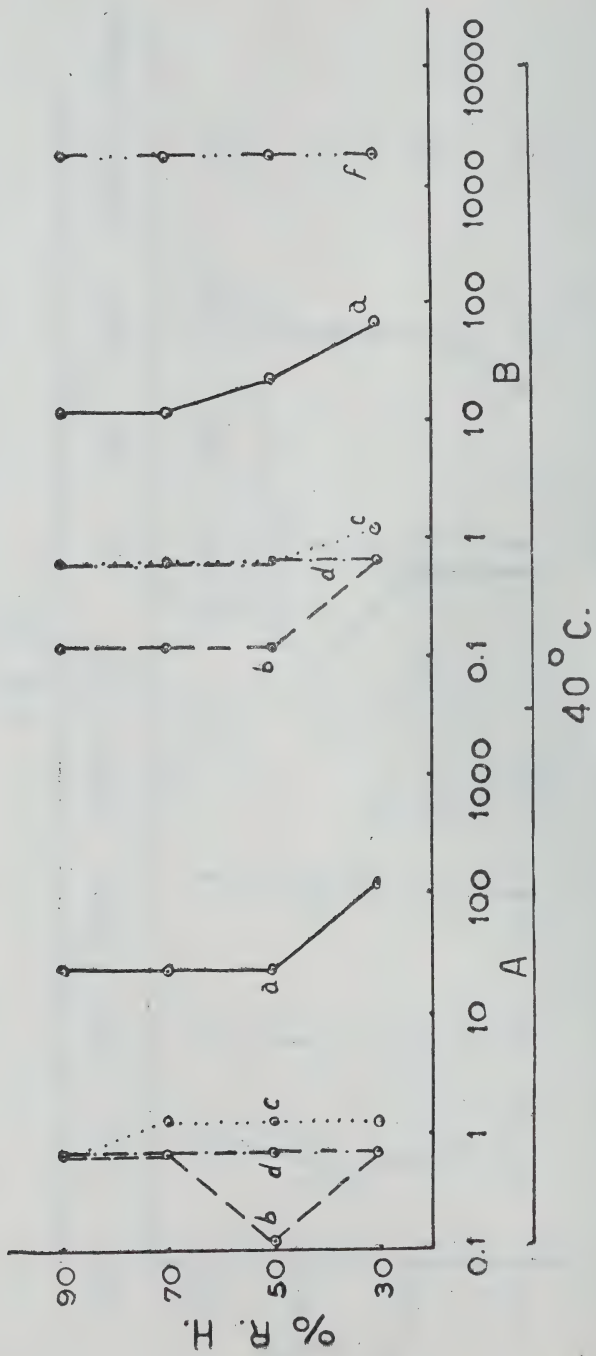
% R. H.
90
70
50
30
0.1
1
10
100
1000
0.1
1
10
100
1000
10000
A
B
a
b
c
d
e
f
40° C.

Fig 6.

THE SUSCEPTIBILITY OF THE EGYPTIAN CARPENTER ANT, CAMPONOTUS MACULATUS AEGYPTIACUS EMERY TO INSECTICIDES

by

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Introduction

Although ants are among the most extensively studied insects yet some ant species received little or no attention of ant specialists.

The control of the Egyptian carpenter ant, **Camponotus maculatus aegyptiacus** Emery, was not studied so far in a satisfactory way. Since this species is one of the most common and economically important ants in Egypt, the present study aimed at testing its susceptibility to insecticides with a trial of finding a successful measure for its control. Thus a test of its susceptibility levels to some of the most common insecticides was carried out in order to detect the most efficient of these materials in the control of this ant.

Literature Rèview

Gibson (1916) found that the American carpenter ant **Camponotus herculeanus pennsylvancius** can be controlled by dusting sodium flouride powder into the nest openings.

Krishna (1936) studied the economic status of the common black ant **Camponotus conpressus** of South India. He found that the number of worker ants was reduced by the fumigation of nests with calcium cyanide, but this did not reach the queen and brood. The best control of this ant was obtained by Krishna (1936) by soaking the nest with a solution of potassium cyanide.

Downes (1940) was able to eradicate a large colony of the carpenter ant, **Camponotus** in a dwelling house by means of Derris powder.

Bibby and Secrest (1943) reported that a single application of sodium flouride (NaF) to the surface of many nests of various ants and slightly within them, by means of small bellow dusters, gave complete control in every case usually within 1—2 days.

Schread and Chapman(1948)studied the effect of chlordane on **Lasius niger americanus** and on **Camponotus herculeanus pennsylvanicus**. They found that wettable chlordane powder at the rate 4 oz. 50% in 50 U.S. glas. water per 75 ft., applied as a course spray to the soil round the roots caused the kill of aphids and 93% of the ants within 48 hours.

Woodside (1949) studied the effect of DDT on different species of **Camponotinae** as **Formica**, **Lasius**. The use of 2.45 lb. of 10% DDT per 1000 sq. feet resulted in stopping of the activity of **Lasius** in 5 weeks. After 8 weeks there was no sign of activity.

Schread (1949) recorded the efficiency of chlordane and octalene dust or wettable powder in the control of **Lasius**, and **Camponotus herculeanus pennsylvanicus.**

Mechell Baher (1951) mentioned that chlordane followed by benzene hexachloride (B.H.C.) has shown the most promise for ant control. He reported that because of the many hazards, the chlorinatad hydrocarbons should be used with great care when applied for ant control.

Other chemicals which proved successful in the control of other ants are Dieldrin, Aldrin, Carbon disulphide and Methyl bromide (U.S.D.A., 1953).

Up to the present study no laboratory toxicological work was carried out to test the susceptibility of the carpenter ant, **Camponotus maculatus aegyptiacus**, to insecticides, (Negherbon, 1959)

Material and Methods

Two methods are used to test the susceptibility of this ant to insecticides, the contact (pick up) and the topical application methods.

Contact (Pick up) method

Ants are exposed to insecticides on impregnated filter papers in Petri-dishes of a diameter of 9 cm. and 1.5 cm. deep. In each dish a filter paper, 9 cms. in diameter previously impregnated (before introduction in the dish) with one ml. of one of the tested insecticides at a certain given concentration following the technique suggested by Busvine (1957), and that used for Aphids and body lice by Solimans (1962).

Solutions of the insecticides to be tested are prepared at different concentrations in acetone. One ml. of each dilution is carefully pipetted and is evenly distributed on each filter paper. The impregnated paper is then left to dry outside the dish and when completely dry it is fitted snugly in the dish which is carefully labelled.

Each dish then received 10 ants and each treatment is replicated four times. Mortality readings of ants that received the different treatments are recorded after 24—hour periods. Check dishes are

supplied with filter papers impregnated each with one ml. of the solvent, (acetone) only.

Experiments are run under laboratory conditions with the temperature ranging from 20—23°C. and about 60% R.H.

The insecticides tested here are: D.D.T., B.H.C., Chlordane, Toxaphene, Aldrin, Dieldrin, Parathion, and Sevin.

Topical Application Technique :

The topical application technique is used for determination of the average individual lethal doses of the different insecticides. For this purpose the same insecticides used in the pick up technique are tested here. Each ant is dosed with $2mm^3$. of the insecticides solution to be tested using the Alga micrometer syringe fitted with a screw driven piston. This insecticide dose delivered topically to the tip of the abdomen of the ant. Ants are handlled carefully to avoid any pressure on their bodies.

After receiving the corresponding treatment ants are placed in Petri-dishes lined with clean filter paper. Ten ants are kept in each dish. Checks are run simultaneously with the experiments using ants receiving each $2mm^3$. of the solvent (acetone) only.

Calibration of the syringe applicator is carefully done to estimate the exact dose delivered through moving of the micrometer screw for a certain number of divisions. Doubtful doses are discarded throughout the experiment. Ants receiving different treatments are kept under laboratory conditions of temperature ranging from 20 — 23°C. and about 60% R.H. Mortality readings are recorded after a 24—hour period in each case.

Results

A — Contact (Pick-up) Meth

I. Susceptibility level of workers and soldiers to some chlorinated hydrocarbon insecticides :

Assessment of th LD 50 and LD 95 of D D T, B H C, Toxaphene, Chlordane, Aldrin, and Dieldrin :-

The doses of some chlorinated hydrocarbons (D D T, B H C Toxaphene, Chlordane, Aldrin and Dieldrin) which bring 50% and 95% mortalities of the workers after a period of 24 hours were determined here. In the contact (pick-up) method applied here the ants are exposed to the different insecticides on impregnated filter papers in Petri-dishes following the procedure described before.

Results obtained in these experiments are summarized in Tables I to VI and plotted in Figs. (1 a to 1 f).

Table I

Susceptibility of the workers of **C.m. aegyptiacus** to D,D.T, using the pick-up method

Concentration of D. D. T. used %	Dose per 1 ml. per dish (micrograms)	Dose available per ant in micrograms	% mortality after 24 hours
0.00025	2.5	0.25	25
0·00125	12.5	1.25	40
0 0025	25	2.5	55
0:005	50	5	65
0.025	250	25	75
0.125	1250	125	90
0.25	2500	250	100
0.5	5000	500	100
1.0	10000	1000	100

Ants tested 40, in 4 replicaties Temp. 20-23°C, R.H. 60 %

LD 50 = 2.083 micrograms of D.D.T. per ant

LD 95 = 187.5 micrograms of D.D.T. per ant

Table II

Susceptibility of ants to B.H.C,

Concentration of B.H.C, used %	Dose per 1 ml. per dish (micrograms)	Dose available per ant in micrograms	% mortality after 24 hours
0.000001	0.01	0.001	30
0.000005	0 05	0.005	40
0.00001	0.1	0.01	60
0.00005	0.5	0.05	80
0.000125	1.25	0.125	90
0.00025	2 5	0 25	100
0.00125	12.5	1.25	100
0.0025	25	2.5	100

Total ants used in eaeh test 40, in 4 replicaties; Temp. 20-23°C. R.H. 60 %

LD 50 = 0.0075 microgram of B H C per ant

LD 95 = 0.1875 « « « «

Table III

Susceptibility of ants to Toxaphene

Concentration of Toxaphene used %	Dose per 1 ml. per dish in micrograms	Dose available per ant in mircograms	% mortality after 24 hours
0.00001	0.1	0.01	30
0.00005	0.5	0.05	35
0.0001	1	0.1	45
0.0005	5	0.5	55
0.001	10	1	60
0.005	50	5	70
0.01	100	10	75
0.05	500	50	85
0.1	1000	100	90
0.5	5000	500	95
1.0	10000	1000	100

Total ants in each test 40, in 4 replicaties, temp. 20-23° C, R.H. 60%

LD 50 = 0.3 microgram of Toxaphene per ant

LD 95 = 500 " " " " "

Table IV

Susceptibility of ants to Chlordane

Concentration of Chlordane used °/₀	Dose per 1 ml. per dish (micrograms)	Dose available per ant in micrograms	°/₀ Mortality after 24 hours
0.00001	0.1	0 01	25
0.00005	0.5	0.05	35
0.0001	1	0.1	45
0.0005	5	0.5	55
0.001	10	1	60
0.005	50	5	70
0.01	100	10	75
0.05	500	50	85
0.1	1000	100	90
0.5	5000	500	100
1.0	10000	1000	100

Total ants used 40, in 4 replicaties, Temp. 20-23° C, R.H. 60°/₀

LD 50 = 0.3 microgram of chlordane per ant

LD 59 = 300 ,, ,, ,, ,, ,,

Table V

Susceptibility of ants to Aldrin

Concentration of Aldrin used °/₀	Dose per I ml. per dish in micrograms	Dose available per ant in micrograms	°/₀ mortality after 24 hours
0.00001	0.1	0.01	25
0.00005	0 5	0.05	40
0.0001	1	0.1	45
0.0005	5	0.5	55
0.001	10	1	70
0.005	50	5	75
0.01	100	10	90
0.05	500	50	100
0.1	1000	100	100
0.5	5000	500	100
1.0	10000	1000	100

Total ants used each test 40, in 4 replicaties; Temp, 20-23° C, R.H. 60 °/₀

LD 50 = 0.3 microgram of Aldrin per ant

LD 95 = 30 ,, ,, ,, ,, ,,

Table VI

Susceptibility of ants to Dieldrin

Concentration of Dieldrin used %	Dose per 1 ml. per dish in micrograms	Dose available per ant in microgaams	°/₀ mortality after 24 hours
0.00001	0.1	0.01	35
0.00005	0.5	0.05	45
0.0001	1	0 1	55
0.0005	5	0.5	60
0.001	10	1	70
0.005	50	5	80
0.01	100	10	90
0.05	500	50	100
0.1	1000	100	100
0.5	5000	500	100
0.1	10000	1000	100

Ants used each test 40' in 4 replicaties, Temp, 20-23°C, R.H, 60 %
LD 50 = 0.075 microgram of Dieldrin per ant
LD 50 = 30 " " " " "

II — Susceptibility levels of ants to the organic phosphorous compound, Parathion.

The 24 hours LD 50 and LD 95 for this ant was also studied in case of Parathion, Records on mortalities are summarized in table VII and also plotted in the curve (Fig. 1 g)

Table VII

Susceptiblity of ants to Parathion

Concentration of Parathion used °/₀	Dose per 1 ml. per dish in micrograms	Dose vailable per ant in micrograms	°/₀ mortality afetr 2 4 hours
0.00001	0.1	0.01	20
0.00005	0.5	0.05	35
0 0001	1	0.1	45
0.0005	5	0.5	65
0.001	10	1	90
0.005	50	5	100
0.01	100	10	100
0.05	100	50	100

Total ants used each test 40, in 4 replicaties, Temp, 20-23° C, R.H. 60°/₀

LD 50 = 0.2 microgram of Parathion per ant

LD 95 = 3 ,, ,, ,, ,, ,,

III - Susceptibility levels of ants to one of the Carbamates, Sevin. Doses which bring the 24 hours LD 50 and LD 95 for Sevin, one of the carbamates were determined here. Results are recorded in Table VIII and plotted in the curve (Fig. 1 h.)

Table VIII

Susceptibility of ants to Sevin

Concentration of Sevin used %	Dose per 1 ml. per dish in micrograms	Dose available per ant in micrograms	% mortality after 24 hours
0.00001	0.1	0.01	20
0.00005	0.5	0.05	30
0.0001	1	0.1	40
0 0005	5	0.5	50
0.001	10	1	55
0.005	50	5	65
0.01	100	10	70
0.05	500	50	80
0.1	1000	100	85
0.5	5000	500	95
1	10000	1000	100

Number of ants used 40 in 4 replicaties, Temp. 20-23° C. R.H. 60%

LD 50 = 0.5 microgram of Sevin per ant

LD 95 = 500 " " " " "

A summary of the data on the susceptiblity levels of various insecticides applying this impregnation technique used here appears in the following Table IX.

Table IX

Summary of the data on the su ceptibility levels of **C.m. aegyptiacus** to the chlorinated hydrocarbons, phosphorous and

carbamate compounds

Insecticides		Suscptibility levels in micrograms / ant	
		LD	LD 95
Chlorinated Hydrocarbons	D.D.T.	2.083	187.5
	B.H.C.	0.0075	0.1875
	Toxaphene	0.3	500
	Chlordane	0.3	300
	Aldrin	0.3	30
	Dieldrin	0.075	30
Phosphorous compound	Parathion	0.2	3
Carbamate compound	Sevin	0.5	500

B — Topical Application Method

I — Susceptibility Levels of Ants (Soldiers and Workers) to Some Chlorinated Hydrocarbons Insecticides.

Assessment of the *LD* 50 and *LD* 95 of some Chlorinated hydrocorbons, D.D.T. B.H.C. ; Toxaphene, Chlordane: Aldrin and Dieldrin:-

The LD 50 and *LD* 95 of D.D.T. , B.H.C. , Toxaphene, Chlordane, Aldrin, Dieldrin when applied topically are determined here. Each ant received on the tip of its abdomen the insecticide solution to be tested using Alga micrometer syringe, fitted with a screw draw

piston. Ants are handled gently to avoid any pressure following the technique suggested by Busvine (1957) and which was used by Soliman (1962) for termites. Each of the treated ants is kept within a clean petri-dish for observation. Checks are run simultaneously along with the experiments using ants dosed with 2 mm^3 of the solvent, acetone only in the procedure described before.

Results obtained in these experiments are summerized in Tables (X to XV) and plotted in curves (Figs. 2 a to 2 f).

Table X

usceptibility levels of ants to D.D.T applied topically by

the micrometer syringe

Concentration of D D.T. in acetone %	Dose per ant amount of D.D.T. in 2 c mm of acetone in micrograms	°/₀ mortality after 24 hours
0.00025	0.005	25
0.00125	0.025	30
0.0025	0.05	40
0.005	0.1	55
0.025	0.5	75
0.125	2.5	85
0.25	5	95
0.5	10	100
1	20	100

Total ants used in each test 50, Temp. 20-23° C., R.H. 60 °/₀

LD 50 = 0.084 microgram of D.D.T. per ant

LD 95 = 5 ,, ,, ,, ,, ,,

Table XI

Susceptibility levels of ants to B.H.C: applied topically

Concentration of B.H.C. in acetone %	Dose per ant amount of B.H.C. in 2 c mm of acetone in micrograms	% mortality after 24 hours
0.000001	0.00002	30
0.000005	0.0001	40
0.00001	0.0002	45
0.00005	0.001	60
0.000125	0.0025	65
0.00025	0.005	75
0.00125	0.025	90
0.0025	0.05	100
0.005	0.1	100

Total ants used in each test 50, Temp; 20-23° C. R.H. 60 %
LD 50 = 0.000466 microgram of B.H.C. per ant
LD 95 = 0.0375 " " " " "

Table XII

Susceptibility levels of ants to Toxaphene applied topically

Concentration of Toxaphene in acetone %	Dose per ant amount of Toxaphene in 2 c mm of acetone in micrograms	% mortality after 24 hours
0.00001	0.0002	30
0.00005	0.001	40
0.0001	0.002	45
0.0005	0.01	50
0.001	0.02	55
0.005	0.1	60
0.01	1.2	65
0.05	1	75
0.1	2	85
0.5	10	95
1	20	100

Total ants used in each 50, Temp. 20-23° C., R.H. 60 %
LD 50 = 0.01 microgram of Toxaphene per ant
LD 95 = 10 " " " " "

Table XIII

Susceptibility levels of ants to Chlordane, doses applied topically by the micrometer syringe

Concentration of Chlordane in acetone %	Dose per ant amount of Chlordane in 2 c mm of acetone in micrograms	% mortality after 2 4 hours
0.00001	0.0002	20
0.00005	0.001	30
0.0001	0.002	35
0.0005	0.01	40
0.001	0.02	50
0.005	0.1	60
0.01	0.2	70
0.05	1	80
0.1	2	90
0.5	10	100
1	20	100

Total ants used in each 50; Temp; 20-23° C; R.H. 60%
LD 50 = 0.02 microgram of Chlordane per ant
LD 95 = 6 ,, ,, ,, ,,

Table XIV

Susceptibility levels of ants to Aldrin, applied topically

Concentratiou of Aldrin in acetone%	Dose per ant amount of Aldrin in 2 c mm of acetone in micrograms	% Mortality after 2 4 hours
0.00001	0.0002	20
0.00005	0.001	30
0.0001	0.002	40
0.0005	0.01	45
0.001	0.02	60
0.005	0.1	65
0.01	0.2	70
0.05	1	80
0.1	2	85
0.5	10	100
1	20	100

Total ants used in each 50. Temp, 20-23° C .; R. H. 60%
LD 50 = 0.0133 microgam orf Aldrin per ant
LD 95 = 7.33 ,, ,, ,, ,, ,,

Table XV

Susceptibility levels of ants to Dieldrin applied topically

Concentration of Dieldrin in acetone %	Dose per ant amount of Dieldrin in 2 c mm in micrograms	% Mortality after 24 hours
0.00001	0.0002	25
0.00005	0.001	35
0.0001	0.002	45
0.0005	0.01	55
0.001	0.02	65
0.005	0.1	70
0.01	0.2	80
0.05	1	85
0.1	2	90
0.5	10	100
1	20	100

Total ants used in each 50, Temp. 20-23° C. R.H. 60 %

LD 50 = 0.006 microgram of Dieldrin per ant

LD 95 = 6 ,, ,, ,, ,, ,,

II — Susceptibility levels of ants to one of the organic phosphorous compounds (Parathion) .

The doses of parathion which when applied topically to ants cause 50 % and 95 % mortalities after a period of 24 hours were determined here. This is a measure of susceptibility of the ant to this insecticide. Records on mortalities are summarized in Table XVI and also plotted in the curve (Fig. 2g).

Table XVI

Susceptibility of ants to Parathion

Concentration of Parathion in actone %	Dose per ant amount of Parathion in 2 c mm of actone in microgram	% Mortality after 2 4 hours
0.00005	0.001	25
0.0001	0.002	40
0.0005	0.01	55
0.001	0.02	65
0.005	0.1	80
0.01	0.2	100
0.05	1	100

Total ants used in each 50, Temp. 20-23° C. R.H. 60%

LD 50 = 0.00733 microgram of Parathion per ant

LD 95 = 0.175 " " " " "

III — Susceptibility levels of ants to the Carbamate, Sevin. Doses of Sevin which when applied topically to soldiers and workers bring 50 % and 95 % mortalities after 24 hours period, were determined. Records on mortalities are summarized in Table XVII and also plotted in the curve (Fig. 2h).

Table XVII

Susceptibility of ants to Sevin

Concentration of Sevin in acetone %	Dose per ant amount of Sevin in 2 c mm of actone in micrograms	% Mortality after 24 hours
0.00001	0.0002	20
0.00005	0.001	25
0.0001	0.002	30
0.0005	0.01	40
0.001	0.02	45
0.005	0.1	50
0.01	0.2	60
0.05	1	70
0.1	2	80
0.5	10	90
1	20	100

Total ants used in each 50, Temp. 20—23°C. R.H. 60 %

LD 50 = 0.1 microgram of Sevin per ant

LD 95 = 15 ,, ,, ,, ,, ,,

A summary on the data susceptibility levels of various insecticides using the topical application method appears in the following Table XVIII.

Table XVIII

Summary of the data on the susceptibility levels of **C. m. aegyptiacus** to some chlorinated hydrocarbons, a Phosphorous compound, and one carbamate compound (Sevin).

Insecticides		Susceptibility levels in micrograms / ant	
		LD 50	LD 95
Chlorinated hydrocarbons	D D.T.	0.084	5.0
	B.H.C.	0.000466	0.0375
	Toxaphene	0.01	10
	Chlordane	0.02	6
	Aldrin	0.0133	7.33
	Dieldrein	0.006	6
Phosphorus compound	Parathion	0.00733	0.175
Carbamate compound	Sevin	0.1	15

Disscussion of Results and Conclusions

The susceptibility of various ants to insecticides was studied by many workers. Gibson (1916) found that **C. h. pennsylvanious** can be controlled by dusting sodium fluoride into the nest openings. Krishna (1936) mentioned that the number of worker ant was reduced by fumigating the nests with calcium cyanide. He obtained best results by soaking the nest with solution of potassium cyanide. Downes (1940) was able to eradicate a large colony of **Camponotus** by Derris powder. Schread and Chapman (1948) studied the effect of Chlordane on **C·h. pennsylvanicus** and other ants, while Woodside (1949) studied the effect of D.D.T. Bibby and others (1943) mentioned that application

of sodium fluoride to the nest gives good results within 1—2 days. Mechell Baher (1951) mentioned that chlordane followed by B.H.C. had shown the most promise for ant control.

In case of **C.m. aegyptiacus** no laboratory studies were previously carried out to test its toxicological susceptibility to different insecticides. In the present study the effect of eight insecticides belonging to three different groups was tested using the contact and the topical application methods. LD 50 and LD 95 values are included in different tables within the text. Table XIX is a summary of these data

Table XIX

For LD 50 and LD 95 of contact (pick up) and topical application methods

	Contact		Topical	
	LD 50	LD 95	LD 50	LD 95
D.D.T.	2.083	187.5	0.084	5
B.H.C	0.0075	0.1875	0.000466	0.0375
Toxaphene	0.3	500	0.01	10
Chlordane	0.3	300	0.02	6
Aldrin	0.3	30	0.0133	7.33
Dieldriin	0.075	30	0.006	6
Parathion	0.2	3	0.00733	0.175
Sevin	0.5	500	0.1	15

In case of the contact method the dose available per ant on the impregnated filter paper differs from the actual doses picked up by individual ant. The amount picked up by the ant in each case is governed by many factors, including time of exposure, temperature and relative humidity during the exposure period. From the data given

above it is noticed that B.H.C. is the most effective while DDT and Sevin are the least.

From these results according to the LD 50 values, in case of different insecticides under the prevailing conditions and applying the impregnation technique, the used insecticides are arranged descendingly according to their efficiency as follows :- B.H.C., Dieldrin, Parathion, Aldrin, Chlordane, Toxaphene, Sevin and DDT.

In the same manner at the 95% level (when the LD 95 values are considered) these insecticides are arranged as follows .-

B.H.C., Parathion. Dieldren, Aldrin, DDT, Chlordane. Taxaphene and Sevin.

B.H.C. (the most effective) is 250 time more effective than DDT (the least effective) at the 50% level and is 1000 times as such at the 95% level.

In case of the topical application method, B.H.C. proved also to be the most effective while the least effective is Sevin. The LD 50 and LD 95 values show that B.H.C. is 150 times effective than DDT. At the 50% level DDT is 1.5 times more effective than Sevin. However at the LD 95 level it is 3 times more effective than Sevin.

This proves that both the impregnation and topical application methods used here for testing the efficiency of insecticides on **C.m. aegyptiacus** are parallel to each other in their validity as toxocological techniques.

Direct application of exactly calibrated doses in case of the topical application technique results in a considerable decrease of the LD 50 and LD 95 values than with the impregnated method.

On basis of the present results B.H.C. is recommended for the control of this ant. The method and rates of application of this insecticide for outdoor and indoor control measures against this ant

are to be decided after running more detailed investigations planned for the near future.

Summary

The susceptibilty of **C. m. aegpytiacus** to some insecticides has been studied using the contact (pick-up) and topical application methods. The insecticides used were some chlorinated hydrocarbons (DDT, B.H.C., Toxaphene, Chlordane, Aldrin, Dieldrin), an organic phosphorous compound (Parathion) and the Carbamate (Sevin). The mortality readings were recorded after a period of 24 hours and the LD 50 and LD 95 were calculated in each case. According to the LD 50 values obtained in the contact method the insecticides used can be arranged as follows : B.H.C., Dieldrin, Parathion, Aldrin, Chlordane, Toxaphene, Sevin and DDT. While in the topical application method the following arrangement has been obtained : B.H.C., Dieldrin, Parathion, Toxaphene Aldrin, Chlordane, DDT and Sevin. When the LD 95 values are considered the following arrangements have been obtained : B.H.C., Parathion, Dieldrin, Aldrin, DDT., Chlordane, Toxaphene and Sevin, and B.H.C. Parathion, DDT., Dieldrin, Chlordane, Aldrin, Toxaphene anb Sevin in both contact and topical application methods respectively.

Thus the ant **C.m. aegyptiacus** is very sensitive to B.H.C. then comes Dieldrin, and the least effective is Sevin.

B.H.C. is recommended for the control of this ant. Its method and rate of application for outdoor use and indoor will be investigated later on.

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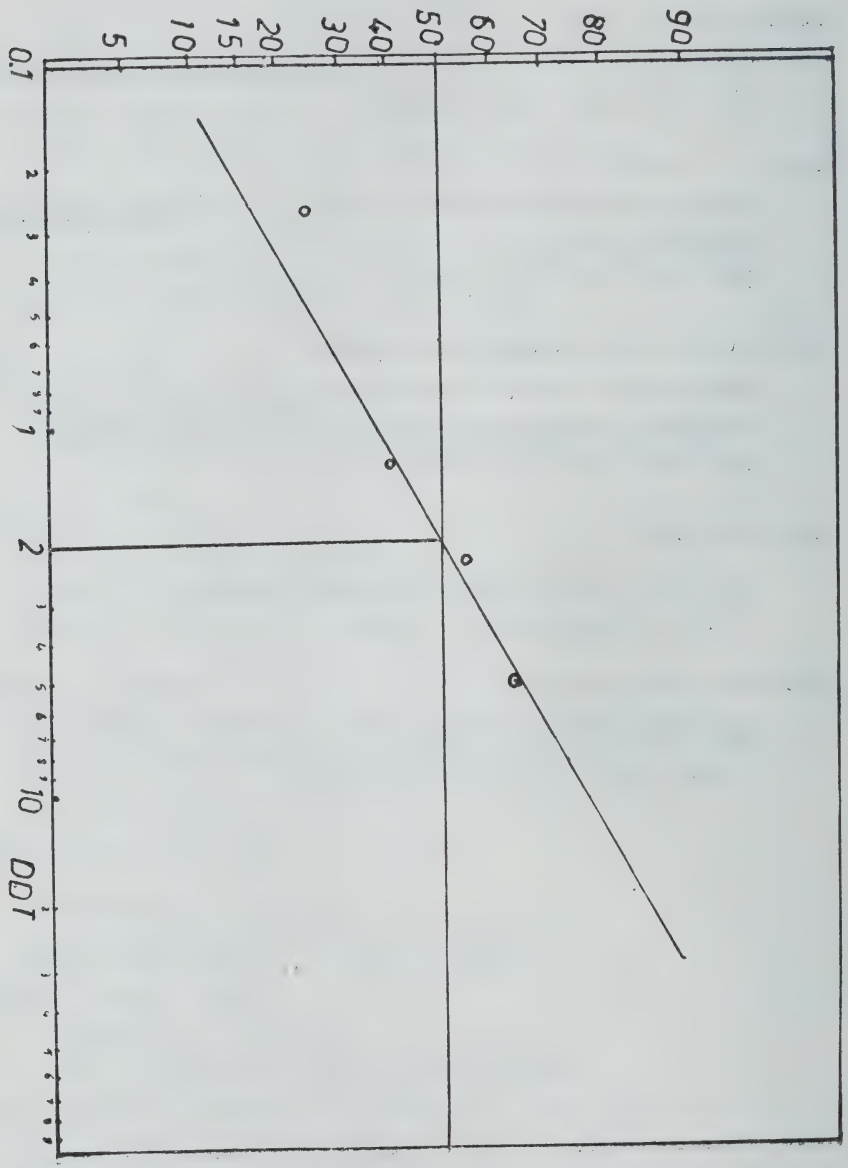

Fig 1

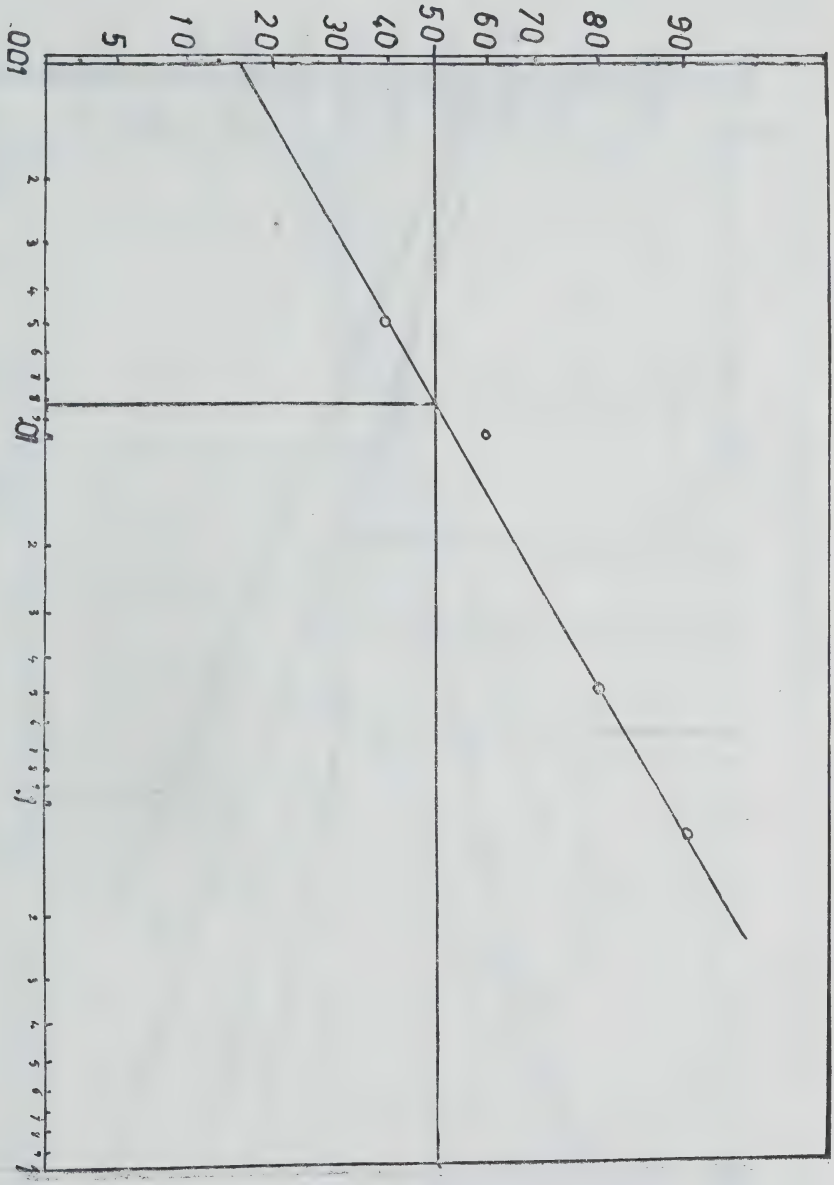

Fig 1b

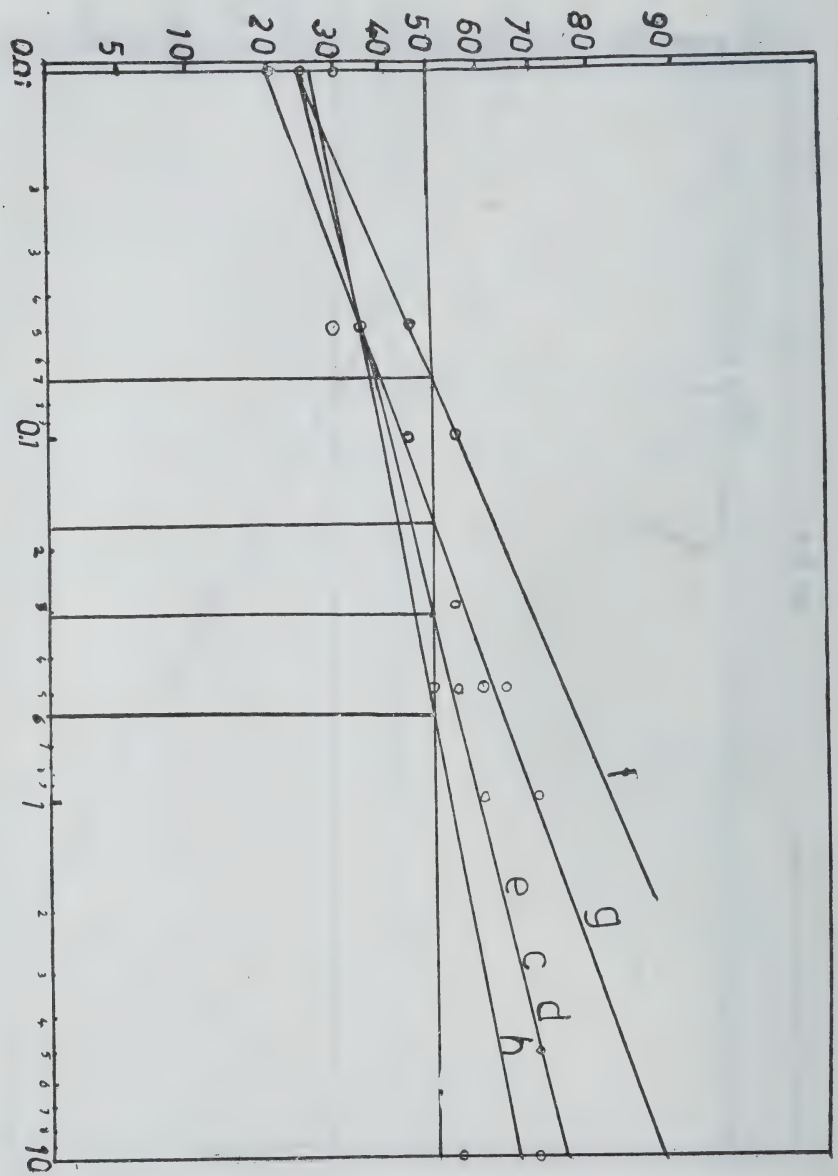

Fig 1a (c,d,e, f,g,h)

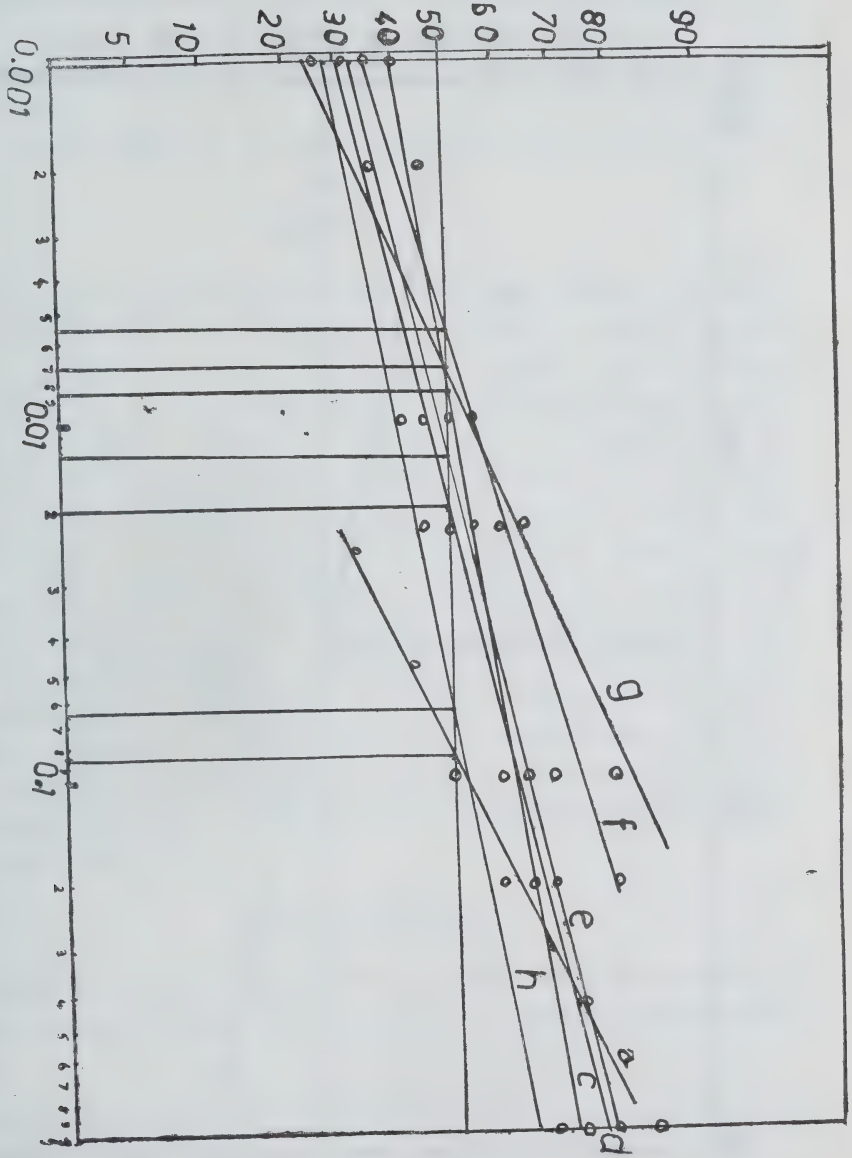

Fig (*a,c,d,e,f,g,h*)

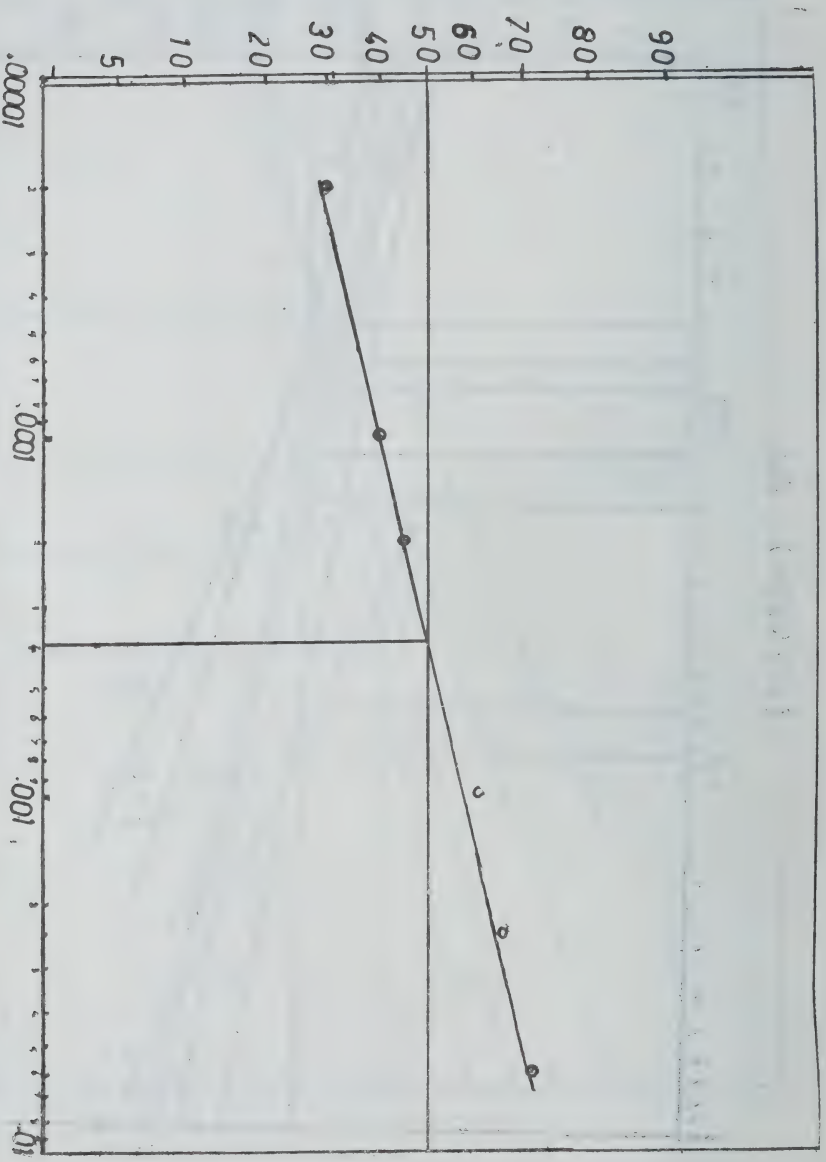

Fig 2

RESPONSE OF DIFFERENT TYPES OF PHOTOGRAPHIC FILMS TO GAMMA-RAYS OVER A WIDE RANGE OF ENERGIES

by

K. A. MAHMOUD, M. A. MAHROUS,** and A. AYYAD****

ABSTRACT

Different types of commercial films (KODAK, ADOX, ILFORD 1 and ILFORD 3) were investigated forl their response for the radiation emitted from gamma ray sources of different energies starting from 0.667 M.e.v. of Cs^{137} up to 1.25 M.e.v. average energy of Co^{60} and under different conditions of normalities of developer used for processing. The findings reported in this paper proved that respone of KODAK and ADOX films is almost energy independent specially when ILF 3 recponse is not, specially when processed using quarter normal developer. In addition it has been found that the shape of the Characteristic Curve of any of the above mentioned commercial films is affected by the normality of developer in case of using the highly complicated gamma ray spectrum of Ra^{226}. The effect of change of developer temperature on the shape of the characteristic curve has also been investigated for a narrow range of $\pm$ 7°F round the normal developing temperature of 65°F and was found to bear relatively small temperature dependence.

INTRODUCTION

When X or gamma rays fall on photograhic film they get absorbed by one of the three interaction processes ; photoelectric.

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*** Health physicist of Protection Department of A.E.E.

Compton, and pair production ([1]). The physical principles underlying the dosimetry of ionising radiation by photographic emulsions are concerned with the fundamental photographic processes, the mechanism of energy transfer from radiation to emulsion, and the response of emulsion to radiation([1]).

Response of different types of films for personnel monitoring purposes has been studied by different authors([123]). Nevertheless the information which could be derived from different references is rather vague. It is the intention of this work to investigate the different parameters which may affect the respone of different types of commercial films to gamma rays of different energies. The picture given in this paper explains the numerical change in the response of these films, due to any variation in one or more of these parameters.

EXPERIMENTTAL

In view of the difference in film response to different types and energies of radiation, the calibration of a photographic film for use in dosimetry would necessitate the determination of characteristic curves for different types of radiation to be monitored. Such a procedure would yield the photographic sensivity as a function of radiation energy for each type of radiation. The photographic effect produced by a particular exposure is often described in terms of a net density, which is equal to the total density minus the back-ground density. Film blackening was measured by means of a densitometer. For any particular film the density exposure curve, in relative units, can in principle vary both with conditions of irradiation and processing.

Because of the complicated variation of the photon absorption coefficient with photon energy([1]), dependence of the photon sensitivity of photographic film is quite high, particulary in the energy region in which photoelectric absorption prevails.

The types of commercial films used for this work were Ilford P.M. 1, Ilford PM. 3, kodak and Adox types. Gamma ray energies were mainly 0.667; 0.85 and 1.25 Mev from Cs^{137} Ra^{226} and Co^{60}

sources respectively. Processing of the different types of films was performed in the usual manner using normal dark room facilities and under controlled conditions of temperature of developer, developer normality and degree of agitation soon after film exposures. The effect of developer temperature on the degree of blackening of the commercial films used was studied for different gamma ray energies. Density measurements of blackening of films was measured on a photo-cell densitometer.

Results and Discussion : The data collected from the series of experiments on different types of films is represented graphically. Figures (1,2,3 and 4) demonstrate the variation of the degree of blackening of the different types of films as a function of log exposure dose in m-reontgens for Cs 137 Ra 226 and Co 60 radiation sources using developers of normalities N, N/2 and N/4 for each film type used. The error expceted in the evaluation of the shapes of the different characteristic curves in figs. 1,2,3 and 4 was computed on basis of the regression Coefficient and was found not to exceed 20%. It is clear that for all chosen conditions of gamma-ray irradiation; film type and specific developing conditions, the characteristic curves were all of the well-known S-shaped form (4). Significant variations in film response were observed.

Varying developer normality confirmed the widely accepted recommendation that best results are obtained when one normal developers are used (5,6), The above mentioned variations were maximum for all types of commercial films used when irradiations were applied from the Ra226 source. This may be attributed to the complicated photographic effect of the heterogeneous mixture of emitted gamma-radiations which cover a range of energies extending from 0.2 to 2.2 Mev with ten gamma-lines in between. Relatively significant variations were observed when Cs137 was used with Kodak and Ilford 1 film types, and when Co 60 was used with Ilford 1 and Ilford 3 film types. The useful range of total exposure dose for each film type varies with irradiation and processing conditions. These ranges can be readily read off the corresponding characteristic curve under

specified operating conditions. The groups of characteristic curves exhibited in Figures (1-4) were used to produce a series of energy response curves by reading off the exposure dose required to produce a certain degree of blackening of a certain gamma-ray energy under fixed developing conditions for the commercial films used in this investigation. The results of these findings are exhibited in Fig. 5. It is evident that there are still varying degrees of energy dependence of film responses for all gamma ray energies used (7). This dependece were minimum over the whole range of gamma ray energies for the Adox and Kodak film types especially when using a developer of unit normality. Significant deficiency of film response was only observed for the Ilford 1 and Ilford 3 film types specially when using developers of N/4 normality.

The shapes of energy-exposure doe curves for the KODAK and ADOX film types for developer normality 1 N, (Figure 5) implies that a film coated with a mixture of their sensitive layers would yield a horizontal energy response curve i.e. energy independant. The effect of developer temperatures was also studied using a developer of unit normality for one film type (3). Figure (6) represents the experimental findings which illustrate that relatively small variations of the degree of blackening of the film type used did occur when cooling or heating within a range of 7°F round the recommended developing temperature which is 65°F. It is unlikely, however, that temperature variations during developing would amount to more than 1 or 2°F and that it would not interefere in the reliability of the degree of blackening under normal operating conditions.

CONCLUSION

On account of the above mentioned deta it can be concluded that the ideal technique for calibration of the response of different commercial films, is by the use of gamma - ray sources of different mono-chromatic energies. It can also be recommended to use Kodak and Adox type commercial films for film Badge dosimetry in the wide range of energy to which occupation personnel are exposed. The temperature effect on the processing procedure should always be controlled in order to avoid any change in temperature which exceed 2°F.

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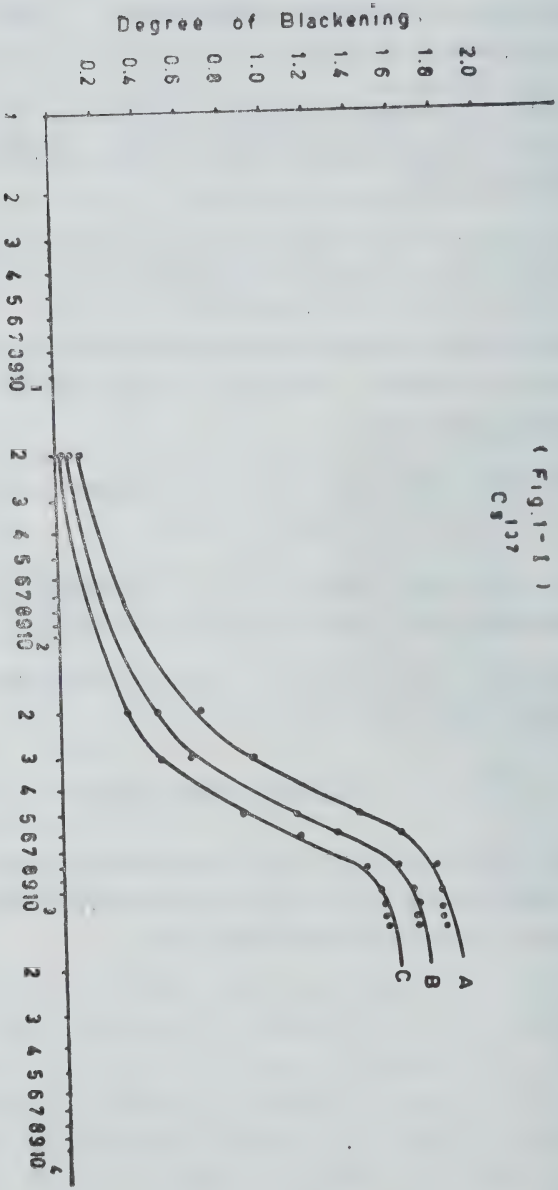
Degree of Blackening
2.0
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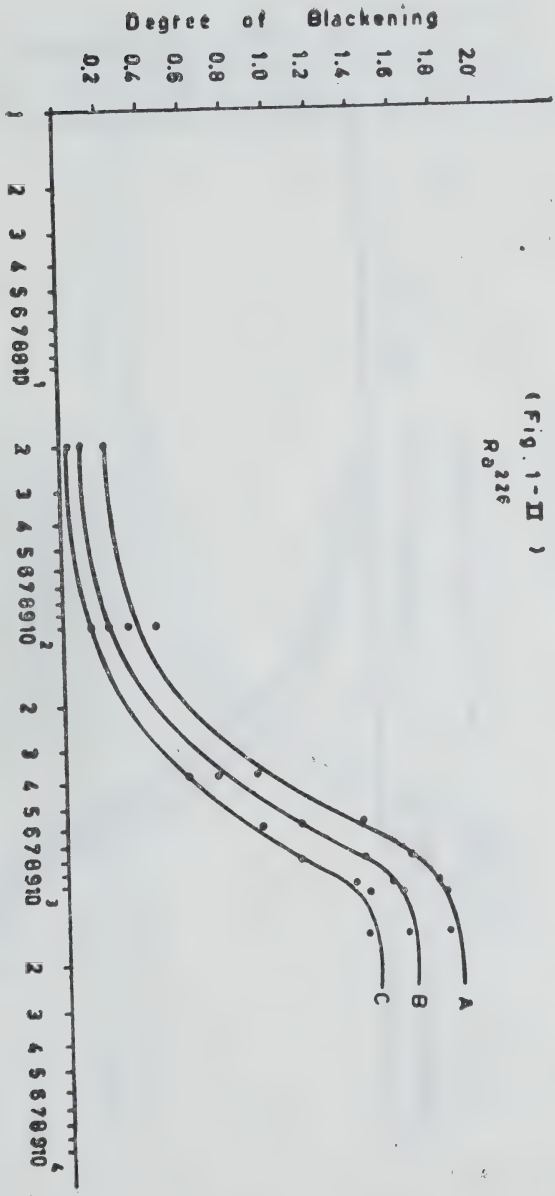
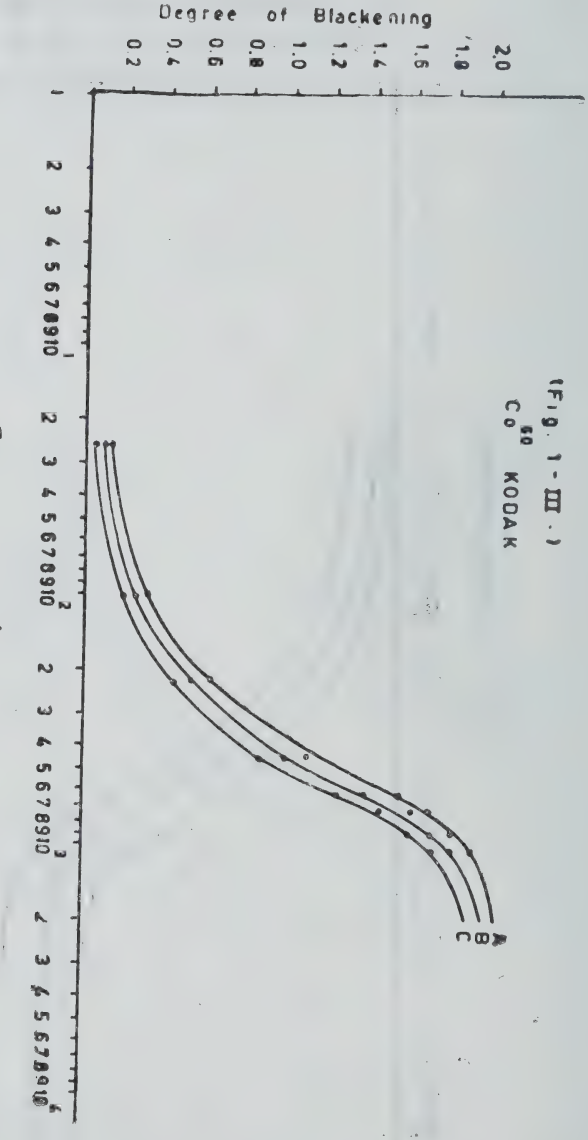
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
Exposure Dose in m.r
A
B
C

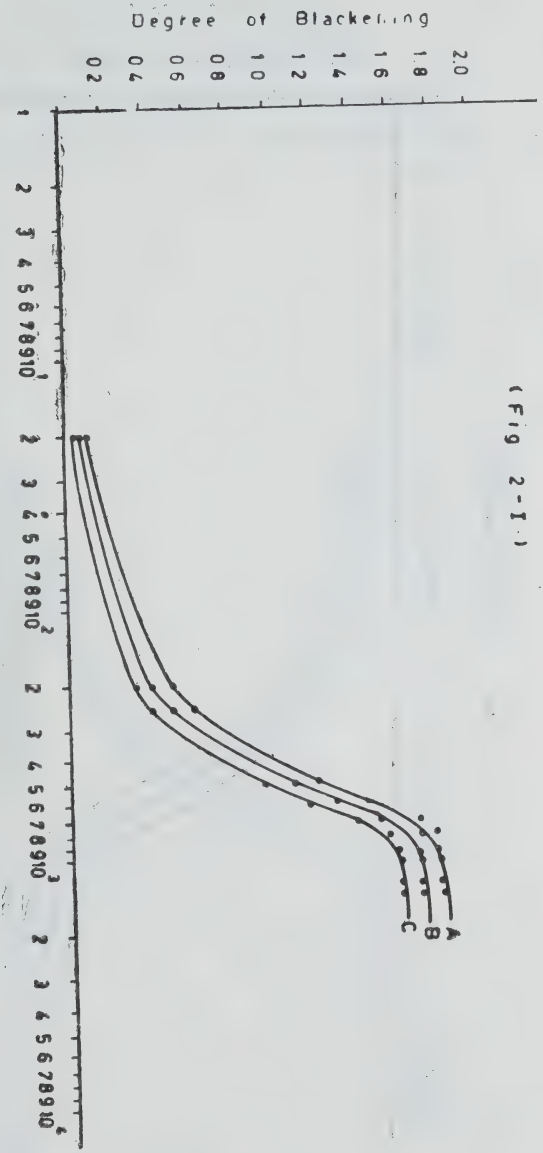
(Fig. 1-1)
Cs^{137}



(Fig. 1-II)
Ra^{226}



(Fig. 1 - III .)
Co^{60} KODAK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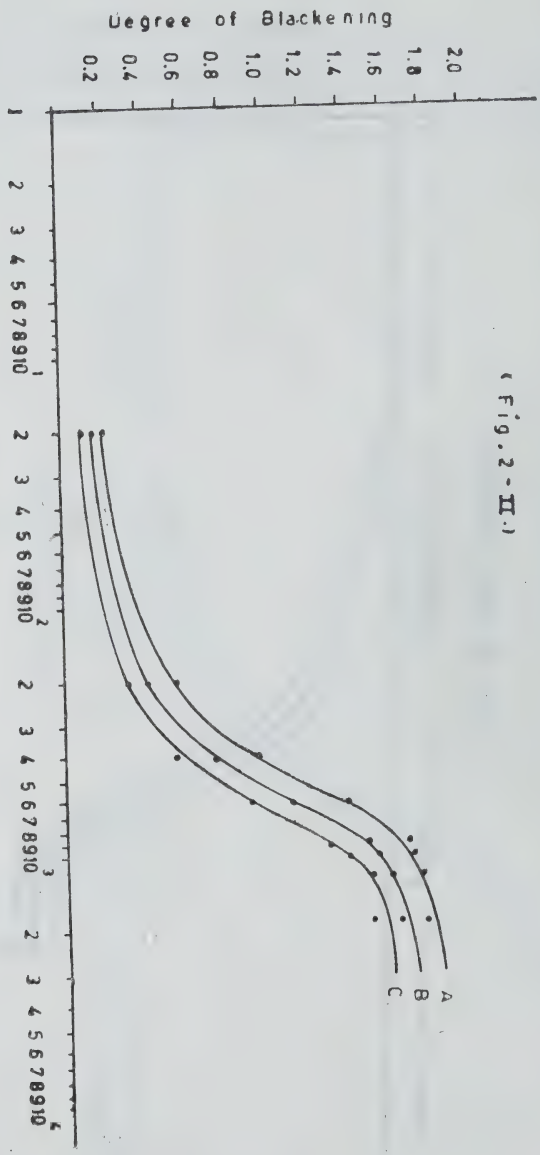
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
A
B
C
Exposure Dose in mr

(Fig 2-I.)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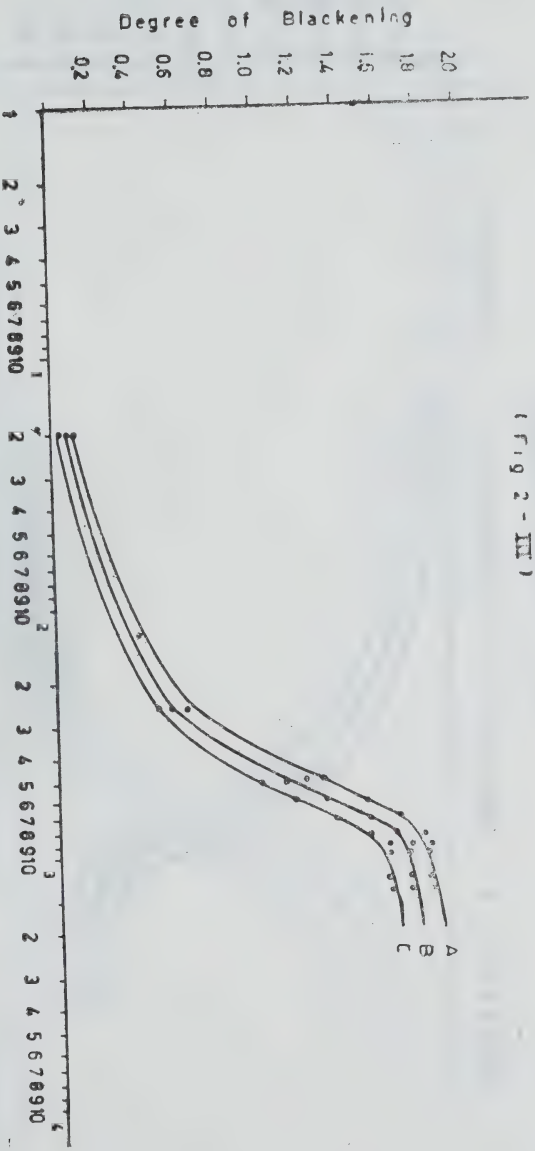
A
B
C
Exposure Dose in m.r

(Fig. 2 - II.)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1.4
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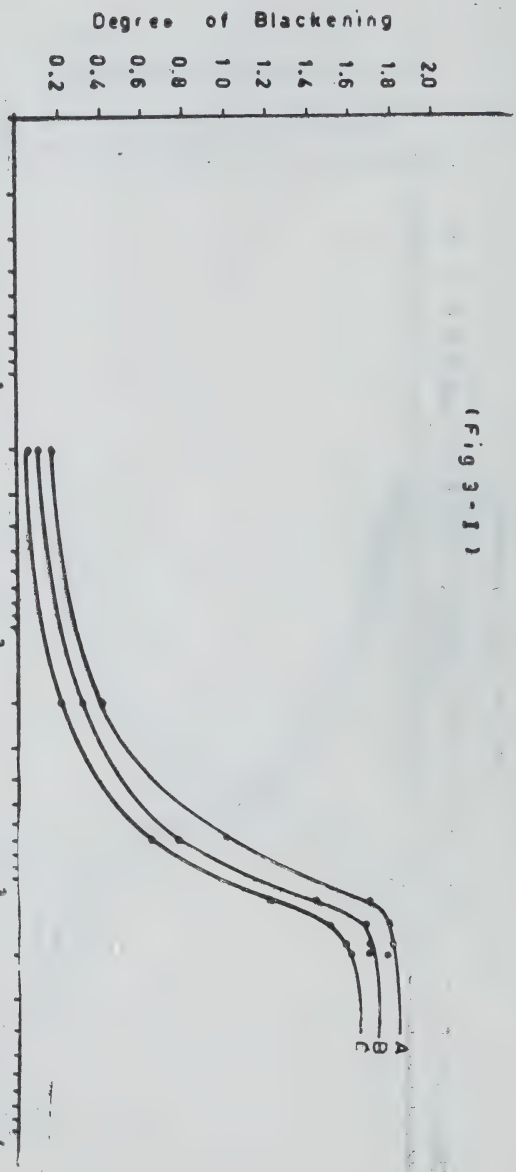
A
B
C
Exposure Dose in m.r.

(Fig 2 - III)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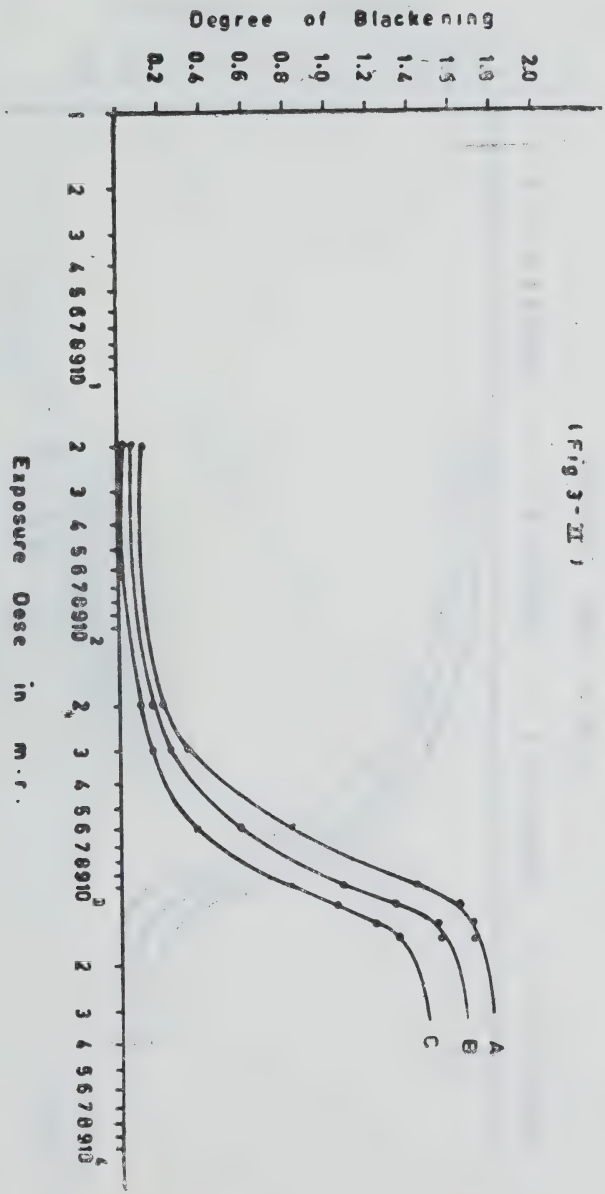
0.6
0.4
0.2
A
B
C
Exposure Dose in m r

(Fig 3-I)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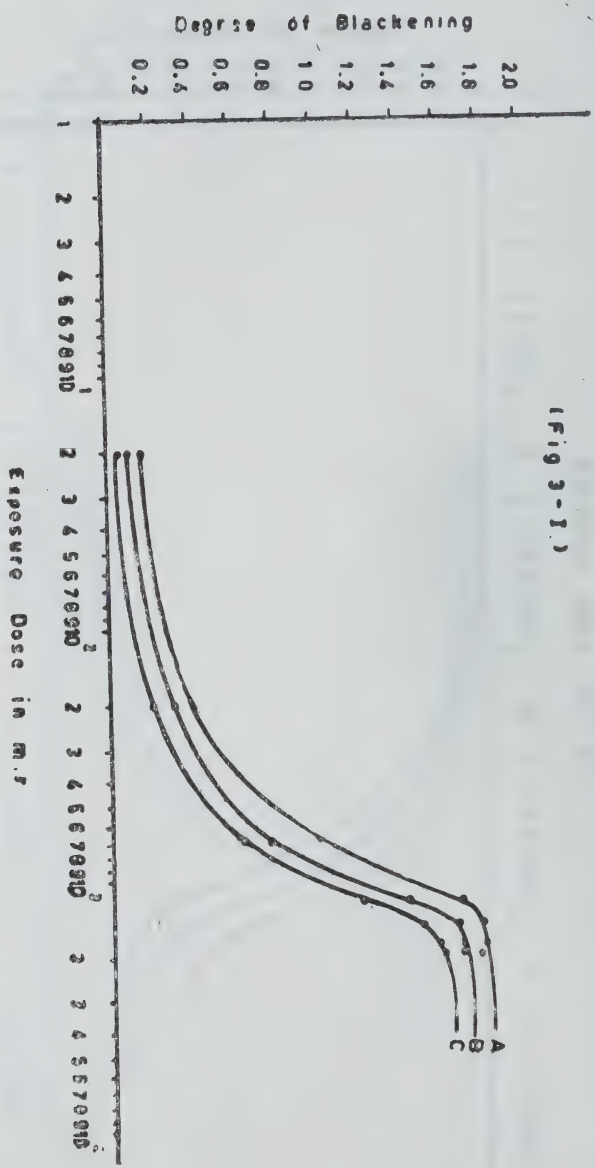
A
B
C
Exposure Dose in m.r.

(Fig 3-II)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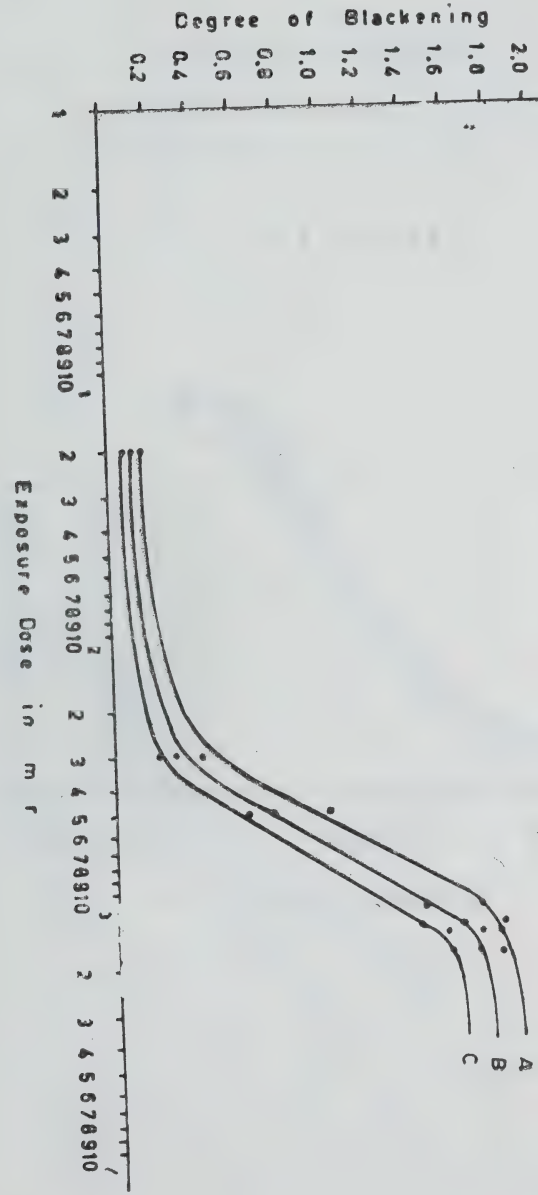
0.4
0.2
A
B
C
Exposure Dose in mr

(Fig 3-I.)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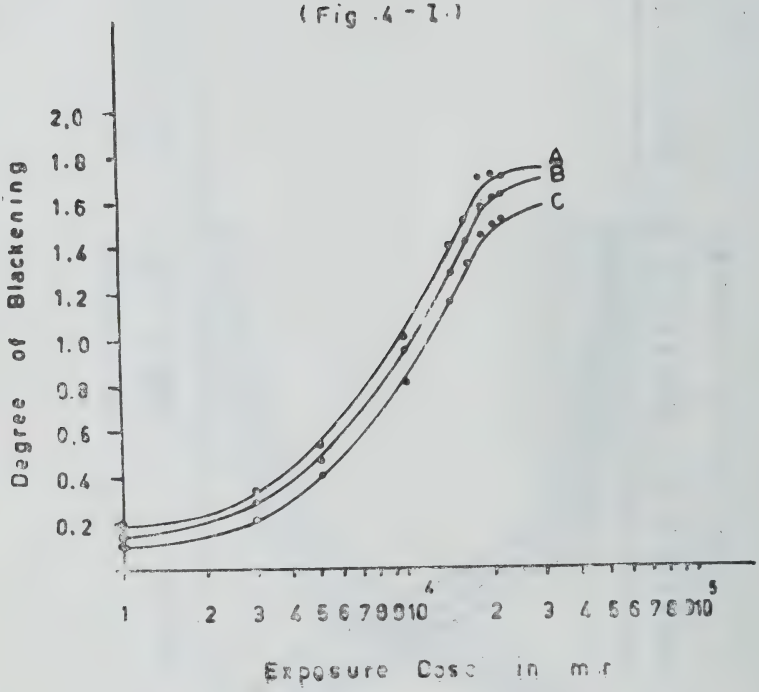
1.0
0.6
0.4
0.2
A
B
C
Exposure Dose in mr

(Fig 3-III)

(Fig .4 - I.)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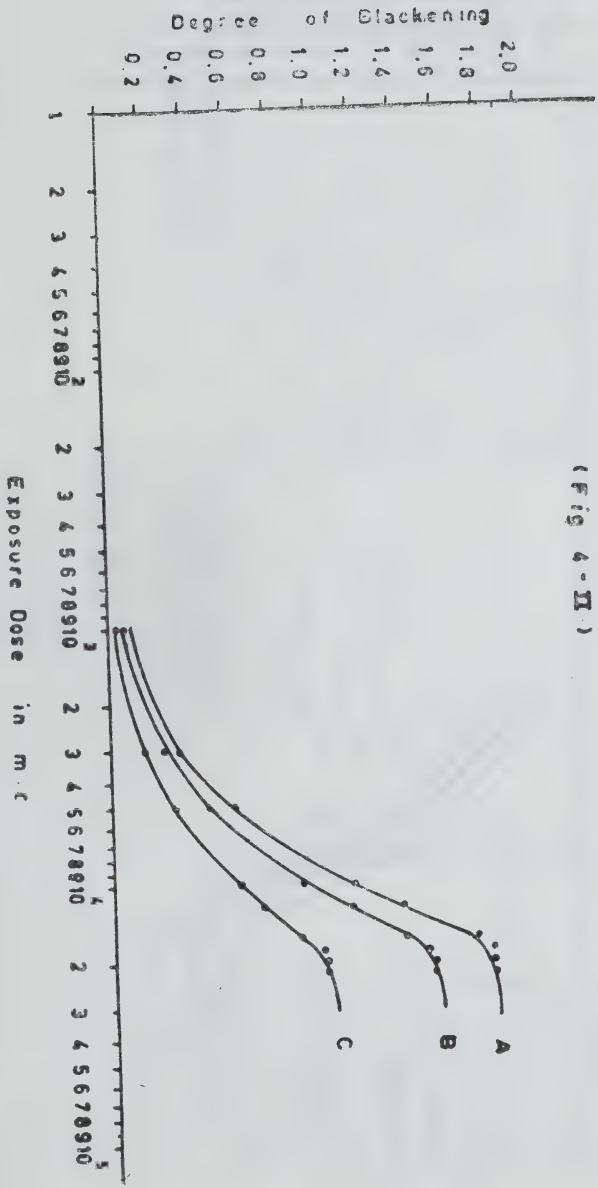
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
A
B
C
1
2 3 4 5 6 7 8 9 10
4
2 3 4 5 6 7 8 9 10
5
Exposure Dose in mr


Degree of Blackening
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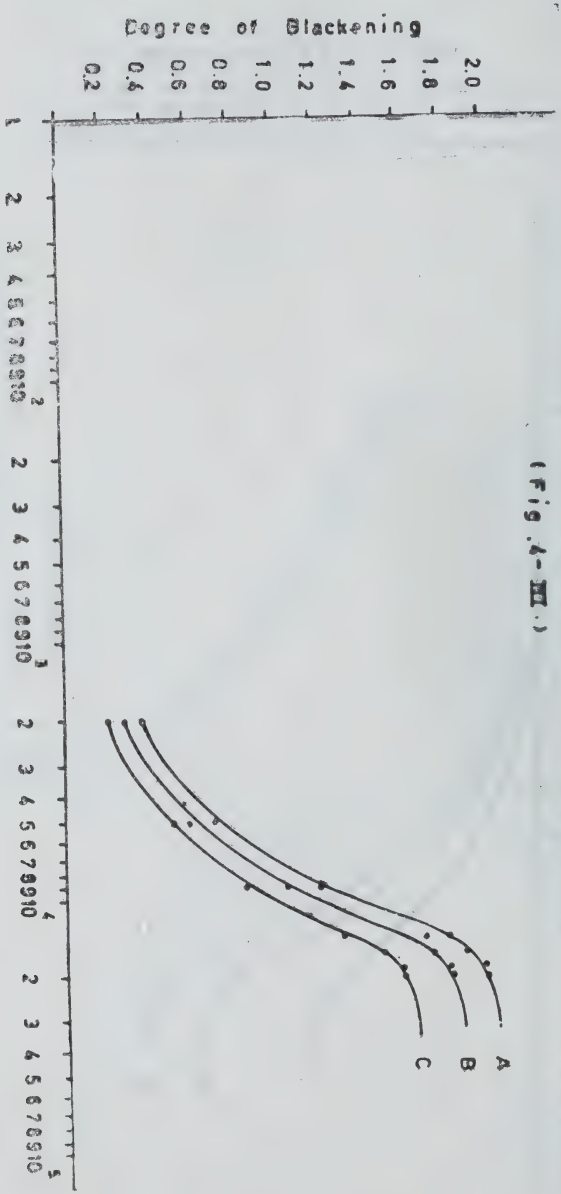
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
A
B
C
Exposure Dose in mr

(Fig 4-II)


Degree of Blackening
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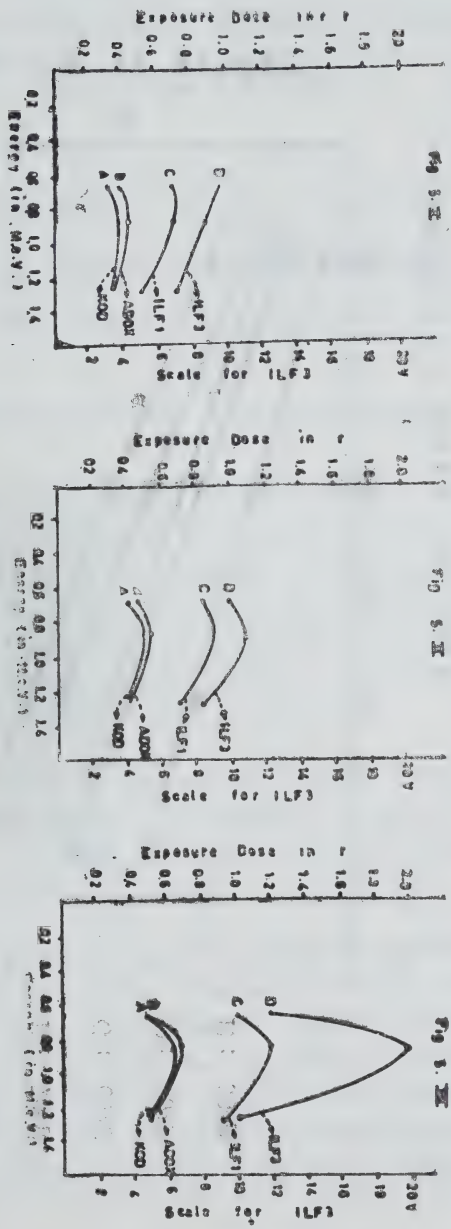
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
A
B
C
Exposure Dose in m.r.

(Fig. 4-III.)


Exposure Dose in r
Scale for ILF3
Fig 5. II
Exposure Dose in r
Scale for ILF3
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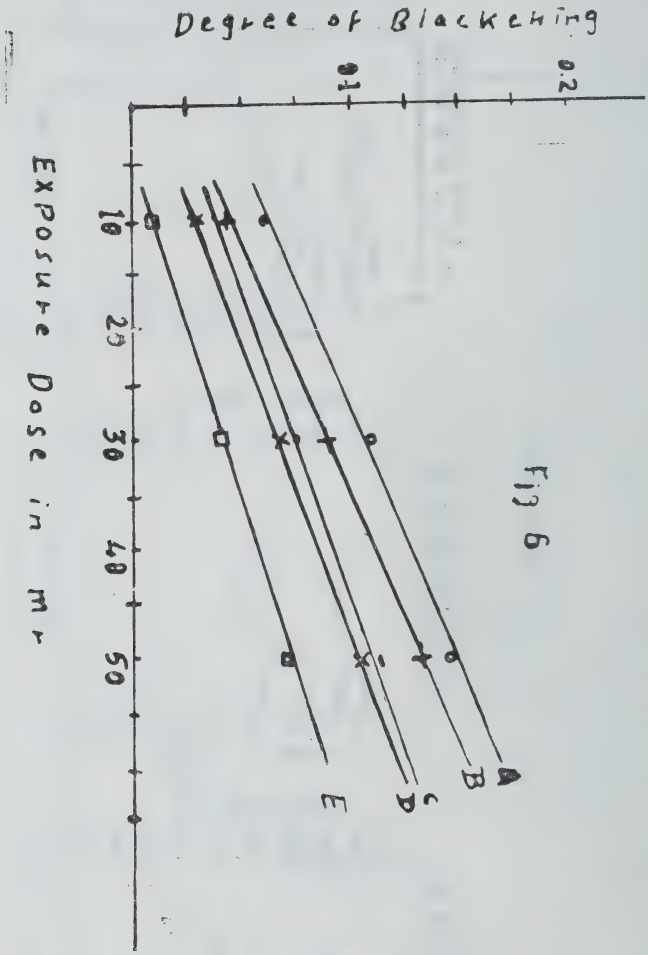

Fig 6

A: 72°F

B: 70°F

C: 65°F

D: 60°F

E: 58°F

STUDIES ON AMPHIBIAN ENDOCRINES
1. THE PITUITARY GLAND OF BUFO REGULARIS REUSS

by

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INTRODUCTION AND HISTORICAL

The maculated toad, **Bufo regularis** Reuss, is the commonest amphibian in Egypt. This toad has special interest, since it is the classical example used in the academic studies of Zoology in our laboratories. Moreover, **Bufo** seems to be an excellent test animal for physiological work. Therefore, this amphibian has received considerable attention from Egyptian zoologists. However, no work has so far been done on the endocrine system of this animal.

The main aim of the present investigation is to give a detailed description of the morphology and histology of the pituitary gland of **Bufo regularis.** This paper will be the first of a series of papers on the endocrine glands of this animal.

The morphology of the amphibian pituitary gland has been studied by Charipper (1931 and 1937, in **Necturus**), Roofe (1937, in **Amblystoma**), Aplington (1942, in **Necturus**), Copeland (1948, in **Triturus**), Charipper and Martorano (1948, in **Xenopus**) and Miller and Robbins (1955, in **Taricha**). Other less detailed accounts of this subject are those of Tilney (1911) on **Necturus** and **Diemyctelus**, of Herring (1913) on **Bufo vulgaris,** of Stendell (1914) on various urodeles and

anurans. of Atwell (1921) on **Amphiuma** and other urodeles and of de Beer (1926) on the frog and the newt.

MATERIAL AND METHODS

Sexually mature specimens, used for the present investigation, were collected at a particular time of the year (June). The pituitary glands were dissected, following decapitation, and usually removd from the brain case along with the whole brain. The meterial was fixed in Zenker-formol and corrosive-formol. After fixation the material was trimmed in order to obtain only the pituitary gland and a small part of the brain to which the gland is attached. Longitudinal and cross sections were then cut serially at 4 u. The sections were stained with Heidenhain's azan stain which proved to be very satisfactory.

OBSERVATIONS

The pituitary gland lies in a shallow depression in the parasphenoid bone, which latter constitutes the ventral skeletal element of the brain case. In situ, the ventral aspect of the gland is a flattened disc-like structure, which is situated behind the infundibular region of the brain, which latter lies just posterior to the optic chiasama (Fig, 1). The infundibulum is relatively large and extends backwards for a considerable distance, thus the pituitary gland is shifted far posteriorly and comes to lie ventral to the medulla oblongata (Fig. 1). The infundibulm is more or less egg-shaped with the narrower end directed posteriorly, and measures about 1.5 - 2 mm in the antero-posterior direction.

The pituitary gland of **Bufo** is made up of two componetns, namely, the the pars glandularis (adenohypophysis) and the pars nervosa (neurohypophysis). The former is subdivided into three regions which are referred to as the pars tuberalis, the pars intermedia and the pars distalis (Figs. 2 and 3).

The pars tuberalis is the most striking glandular region as it represents the smallest part of the gland; it cannot be discerned

anatomically and appears only in the serial sections (Fig. 2). The pars tuberalis is represented by a pair of bilaterally symmetrical small epithelial structures, lying on either side of the median line. These bodies are quite apart from each other and they never meet in the middlle line. The pars tuberalis is plastered to slight grooves in the infundibular floor in front of, and completely separate from, the rest of the pituitary gland (Fig. 2).

The pars tuberalis is bounded dorsally by the pia mater connective tissue membrane of the brain (Fig. 4), and ventrally by small blood vessels, which occasionally penetrate the epithelial tissue. However, the vascularity of the pars tuberalis is still poor as compared with the pars distalis or the pars nervosa.

The pars tuberalis cells, which are about 2-3 layers in thickness, form a region of undifferentiated compact epithelial tissue. These cells are comparatively small and are chromophobic, with scanty cytoplasm. The Cell outlines are not well defined and the appearance of the entire glandular region is that of an elongated multi-nucleated sheet (Fig. 4). The nuclei are prominent and mostly ovoid, occupying the greater portions of the cells as they are usually lying close together.

II. The pars intermedia.

The pars intermedia is situated between the pars nervosa dorsally and the pars distalis ventrally (Figs 2 and 3). It is a flattened, elongated sheet which extends transversely across the antetior portion of the pars distalis. The lateral edges of this sheet or plate are slightly thickened and thus the whole structure presents a more or less dumbbell-shaped form in transverse sections (Fig. 3). The pars intermedia porjects slightly beyond the lateral edges of the pars distalis. These lateral prominences of the pars intermedia extend slightly ventralwards, thus partly embracing the lateral edges of the pars distalis in this region. Moreover, the ventral suface of the pars intermedia is slightly concave to accommodate the pars distalis.

The chief vascular supply of the pars intermedia is by blood

vessels lying on the borders adjoining the pars distalis or the pars nervosa. Accordingly, no evidence of direct vascularization could be found in the pars intermedia and thus, it is the most poorly vascularised glandular region of the pituitary gland (Fig. 5).

The transverse sections reveal the exact form of the dumbbell-shaped pars intermedia, where the plate or middle region is formed of about 5 - 6 layers of cells in thickness, with the thickened prominent edges containing a larger number of layers (Fig. 3). The epithelial cells of the pars intermedia are all alike and differ in structure and staining reactien from those of the rest of the pituitary gland. The cytomplasm is rather homogeneous and slightly basophilic. Although the cell outlines are difficu t to define, yet it should be expected that the pars intermedia cells are polygonal in outline due to the fact that they are closely packed tgether (Fig. 5).

III, The pars distails.

The pars distails represents the largest lobe of the pituitery gland Figs. 2 and 3). It is more or less ovoild in oulline with its slightly larger axis lying transversely. The pars distalis liés ventral to the pars intermedia, but extends posteriorly further than the latter. Accordingly, the pars distalis is the most ventral or ventro-caudal glandular region in the pituitary gland of **Bufo**. The pars distalis never comes in close contact with the pars intermedia, as a definite cleft (Figs. 2 and 3), occasionally occupied by little connective tissue, is present between these two glandular regions. It seems that this cleft may be comparable to the hypophysial cavity found between the pars distalis and the pars intermedia in the mammalian pituitary glands.

The pars distalis is envelopped with a thin connective tissue capsule which occasionally holds blood capillaries. This glandular region consists of a solid mass of cells which is interspersed by delicate connective tissue septa and numerous blood capillaries. Accordingly, the majority of the cells have contact with the blood supply. Such supply is afforded by blood capillaries which are less regularly arranged, so there is little or no cord arrangement in this glandular region.

The pars distalis is most complex in its cellular structure as compared with the other glandular regions of the pituitary gland. After Heidenhain's azan stain the cells of the pars distalis are differentiated into five distinct types, namely two types of acidophils, two types of basophils and one type of chromophobes. Not only can these cells be differentiated by their staining reaction, but also by their size and cytoplasmic granulation.

According to the differential staining properties of the acidophils, two types are recognized. One acidophilic type reacts strongly with the azocarmine component of the dye, thus staining vived crimson. These cells are referred to as azocarmine acidophils (Fig. 6). The second acidophilic type reacts with the orange G component of the dye; thus staining bright yellow to orange. The latter cells are referred to as orange G acidophils (Fig. 6).

On the other hand, the basophils are differentiated into two types on the basis of their visible cytoplasmic inclusions. One basophilic type has a great affinity for the anilin blue component of the dye and has no cytoplasmic inclusions. These cells are referred to as the anilin blue basophils (Fig. 6). The second basophilic type has a lesser affinity to the dye; but has acidophilic secrectory globules in its cytoplasm. The latter cells are referred to as globular basophils.

The chromophobes are usally found in groups scattered throughout the glandular region. However, these chromophobic areas are frequently encountered at the periphery of the pars distalis (Fig. 2) The chromophobes are mostly small rounded cells whose cell outlines are not well defined. The cytoplasm is scant and poorly-stained and the nuclei are large, occupying the greater portions of the cells.

The acidophils are the most numerous of the differentiated cells of the pars distalis. These cells are distributed uniformly throughout the glandular region without a definite pattern. The azocarmine acidophils are more numerous and larger than the orange G acidophils(Fig.6). Moreover, the azocarmine acidophils represent the largest cells in the pars distalis. On the other hand, the orange G acidophils show conspi-

cuous cell outlines and homogeneous fine acidophilic cytoplasmic granules in comparison with the azocarmine acidophils. The nuclei of both types of acidophils are identical in size and structure, more or less rounded, with central conspicuous acidophiiic nucleolus.

The basophils make up a relatively small proportion comparable to the other glandular cells consitituting the pars distalis. The basophils show a tendency to group together and form nests, but occasionally single cells are encountered. The anilin blue basophils are the dominant type of cells, but are smaller than the geobular basophils. The latter are similar in size or slightly smaller than the azocarmine acidophils. The cytoplasm of the anilin blue basophils is uniformly homogeneous and exihibits no definite granulation. On the other hand, the acidophilic spheres of the globular basophils vary in size from just within the limits of detection to relatively conspicuous spheres. These acidophilic spheres vary in amount as they are either scattered or closely packed within the cytoplasm. The nuclei of both types of basophils resemble those of the acidcphils as they exhibit no specificity either in size or chromatin arrangement.

IV. The pars nervosa

From the ventral floor of the infundibulum issues the infundibular process which curves dorsally at a sharp angle just anterior to the pars distalis (Fig. 2). This infundibular process is thickened at its posterior extremity to form the pars nervosa. Midway along its length, and before it expands posteriorly to form the pars nervosa, the infundibular process is thickened forming a considerable swelling of nervous tissue (Fig. 2). This swelling looks like the pars nervosa, but its histological structure is different from that of the latter and resembles the brain substance. The infundibular process is extremely slender, and thus the pituitary gland is suspended from the brain only by a fragile solid tube. Accordingly, extreme care should be taken in dissecting the pituitary gland, otherwise its connection to the brain is broken.

Like the pars intermedia, the pars nervosa is plate-like, but the

latter differs from the former mainly in two points, as it is more thick and is more or less uniform in thickness throughout its whole width (Fig. 3). The pars nervosa lies dorsal to and in very close contact with the pars intermedia and these two regions are separated from each other only by a thin connective tissue membrane and small blood vessels(Fig.5). Accordingly, the pars glandularis is closely attached along its antero-dorsal part to the pars nervosa.

The pars nervosa is well vascularized as it contains many blood vessels (Fig. 5). The pars nervosa consists almost entirely of rather compact fibrous tissue, throughout which are distributed several neuroglia nuclei (Fig 5). The latter are of two types. The first and the most numerous type is large rounded or ovoid, with little chromatin granules scattered throughout the nucleoplasm. The second type is small, rounded or oval, with chromatic appearance due to the plentiful amount of of chromatin granules found in the nucleoplasm. Moreover, the pars nervosa contains a considerable amount of homogeneous material distributed throughout this nervous lobe in an irregular fashion (Fig.5). This material stains blue after Heidenhain's azan stain, and most probably represents a colloidal secretion. This colloidal material may be in the form of granules or irregular masses, and is more abundant towards the dorsal side of the pars nervosa than elswhere. Some pars intermedia cells may also be distinguished in the pars nervosa, especially in the region in close contact with the pars intermedia.

DISCUSSION

The amphibian pituitaries differ from the case encountered in the pituitary glands of fishes (cf: Rizkalla, 1961 and 1962) in having a more or less homogeneous organization throughout the whole group. However, the amphibian pituitaries bear a close resemblance to those described for most fishes and mammals, as in these two latter groups the pars glandularis of the pituitary gland shows the three characteristic glandular regions, namely, the pars tuberalis (anterior glandular region), the pars anterior or pars distalis (middle glandular region)

and the pars intermedia (posterior glandular region)*

The mamalian pituitary is formed mainly of two lobes which are separated from each other by the hypophysial cavity. These lobes are the anterior (pars distails) and the posterior (pars intermedia and pars nervosa). Since the pars distalis in the pituitary of **Bufo regulris** is the most posterior portion of the gland, thus it should not be referred to as the pars anterior as this nomenclature does not conform well with its position. On the other hand, the pars intermedia and the pars nervosa in the pituitary of **Bufo** are closely united forming a lobe which is comparable to the posterior lobe of the mammalian pituitary, but the former has an anterior position. Accordingly, this combined lobe of **Bufo** would better be referred to as the proximal or neurointermdiate lobe.

Two different conditions of the pars tuberails are encountered in the amphibian pituitaries studied so far. Firstly, the pars tuberalis is a continuation of the pars distalis towards the cephalic end as in Urodela (Atwell, 1921; de Beer, 1937). Secondly the pars tuberalis is completely separated from the pars distalis as in Anura (Stendell, 1914; de Beer, 1926; Charipper and Martorano, 1948 as well as in **Bufo regularis** of the present investigation).

The cells of the pars tuberalis differ in their staining reaction in the different amphibian pituitaries. A basophilic type of cells has been recorded in the frog and the newt (de Beer, 1926) and in **Necturus** (Charipper, 1931 and Aplington; 1942). Charipper (1937) stated that in **Necturus** the basophilic cells of the pars tuberalis resemble in all respects those of the pars intermedia. On the other hand, Copeland (1943) recorded chromophobic or weakly basophilic cells in the pars tuberalis of **Triturus**. In the present investigation only chromophobic cells were detected in the pars tuberalis of **Bufo**

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* The anterior, middle and posterior glandular regions of the teleost pituitary may be comparable to the pars tuberalis, pars anterior or pars distalis and pars intermedia respectively, constituting the pituitary gland of higher vertebrates (cf **Rizkalla, 1962).**

regulairs Roofe (1937) stated that in **Amblystoma** there are very few histological and cytological differences between the cells of the pars distalis and the pars tuberalis, the only difference being that the pars tuberalis lacks definite cord arrangement of its cells.

The pars intermedia in **Bufo regularis** is similar to that described for other amphibians, being constituted only of one cell type which stains basophillically. Morover, the different investigations yield no evidence of direct vascularisation in this lobe of the amphibian pituitary (cf. de Beer, 1926 and D'Angelo. 1941). At well (1919) however, stated that the cell type of this glandular region is chromophobic and the whole lobe is well vascularized.

The pars distalis of the amphibian pituitaries, described by the different authors, shows a variable degree of fusion or separation in relation to the pars intermedia. Thus, a complete separation is recorded in the frog and the newt by de Beer (1926),a case which is similar to that found in **Bufo regularis**. On the other hand, a complete fusion is described in **Necturus** (Aplington, (1942) and in **Xenopus** (Charipper and Martorano, 1948).

The cells constituting the pars distails in **Bufo regularis** (acidophils, chromophobes and basophils are distributed throughout the whole glandular region without being arranged to form a definite pattern. Also, the three types of cells mentioned above are recorded in the pars distalis of **Necturus** (Charipper, 1931 and 1937 and Green, 1951) and of **Rana** (Ortman, 1956). Roofe (1937) suggested a new term " subdistalis " for a ventro-medial portion of the pars distalis in **Amblystoma** pituitary. The " subdistalis " is formed almost exclusively of acidophils as contrasted with the surrounding basophilic cells of the pars distalis. Copeland (1943), on the other hand, divided the pars distalis of **Triturus** into four areas which are distinguished by different cell types. Four areas of different cell types were described also in the pars distalis of **Tarciha** (Miller and Robbins, 1955). Charipper and Martorano (1948) stated that the rostral area of the pars distalis in **Xenopus** pituitary is heavily vascularized and distinct from

the pars distalis proper as it consists only of weak-staining basophils, with few acidophilic cells. According to the same authors, the pars distalis proper, however, is formed of acidophils, basophils and chromophobes.

SUMMARY

1. The pituitary gland of **Bufo regularis** is situated posterior to a relatively large infundibulum, which latter lies just posterior to the optic chiasma.

2. The pituitary gland is composed of a pars glandularis and a pars nervosa. The former is subdivided into three regions, namely, the pars tuberalis, the pars intermedia and the pars distalis.

3. The pars tuberalis is the smallest part of the gland and is represented by a pair of small epithelial structures, lying on the ventral surface of the infundibulm on either side of the median line. The epithelial cells of this glandular region are of the chromophobic type.

4. The pars intermedia is represented by a flattened, elongated sheet which presents a more or less dumbbell-shaped form in transverse sections. The epithelial cells of this glandular region are all alike and are most probably, closely packed polygonal basophils.

5. The pars distalis represents the largest lobe of the pituitary gland. The cells of this glandular region are differentiated into five distinct types, namely azocarmine acidophils, orange G acidophils, anilin blue basophils, globular basophils and chromophobes. The acidophils are the most numerous cell type, while the basophils are the fewest in this glandular region.

6. The pars nervosa is well vascularized as it contains many blood

vessels. This nervous lobe consists almost entirely of rather compact fibrous tissue, throughout which are distributed two types of neuroglia nuclei. Moreover, the pars nervosa contains a considerable amount of colloidal material which is more abundant towards the dorsal side of this nervous lobe.

ACKNOWLEDGEMENT

The author wishes to express his deep gratitude to Prof. Dr. A. H. Al-Hussaini, Professor of Comparative Anatomy and the head of the Department of Zoology, Ain Shams University, for his continuous help and encouragement and for reading through the manuscript.

LIST OF ABBREVIATIONS

a, bl. bas	anilin blue basophil
az. acd	azocarmine acidophil
b. cp	blood capillary
b.v	blood vessel
bn	brain
c. ts. mb	connective tissue membrane
chr	chromophobe
cl	cleft between pars intermedia and pars distalis
co. ma	colloidal material
inf	infundibulum
inf. pr	infundibular process
n. nu	neuroglia nuclei
ni. l	neurointermediate lobe
o. G. acd	orange G acidophil
op. ch	optic chiasma
p. d	pars distalis
p. i	pars intermedia
p.n	pars nervosa
p.t	pars tuberalis
pi.m	pia mater
sw. n. ts	swelling of nervous tissue

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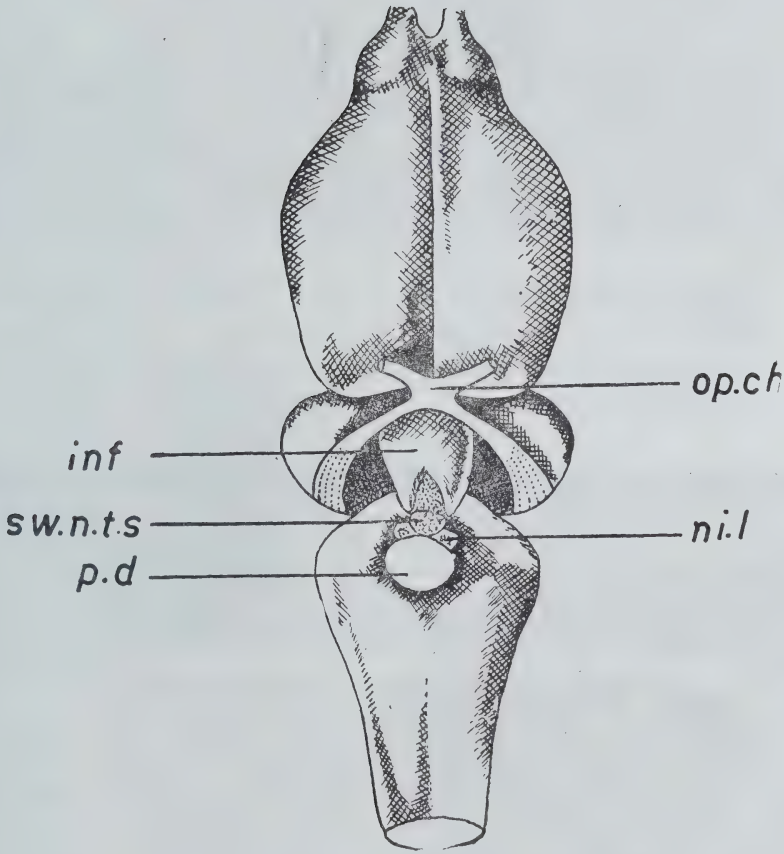

***Fig.* 1** *Ventral view of the brain of* Bufo regularis, *showing the position of the pituitary gland.*

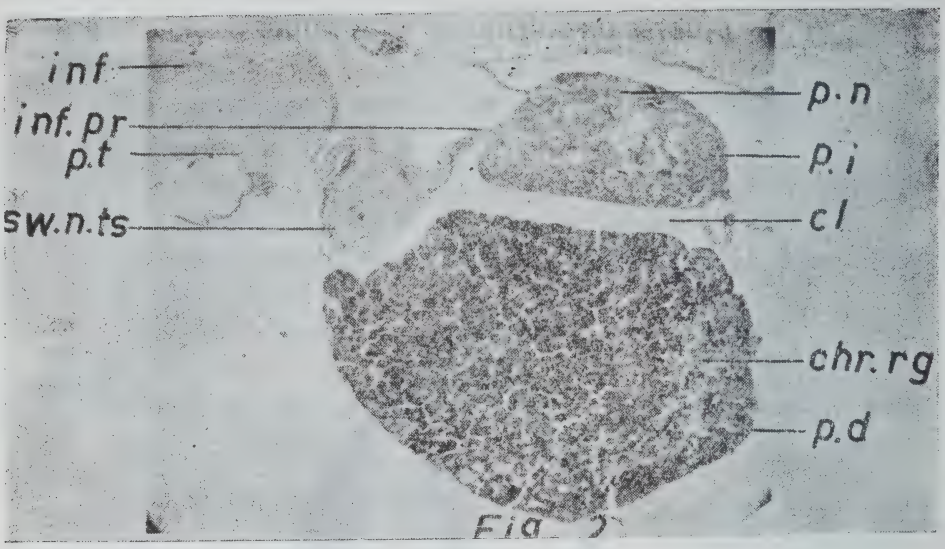

Fig. 2 Photomicrograph of a sagittal section of the pituitay glvnd of Bufo regularis, *showing its various components : pars tuberalis, pars intermedia, pars distalis, pars nervosa and the infundibular process with its swelling nervous tissue.*

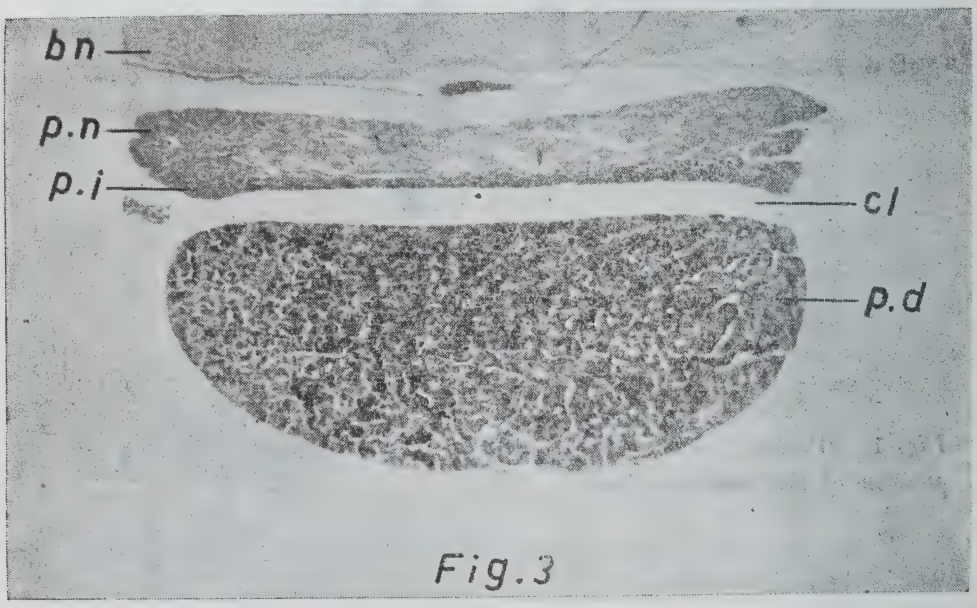

Fig. 3 Photomicrograph of a transverse section of pituitary gtand of Bnfo regularis, *showing the pars nervosa, pars intermedia and pars distalis.*

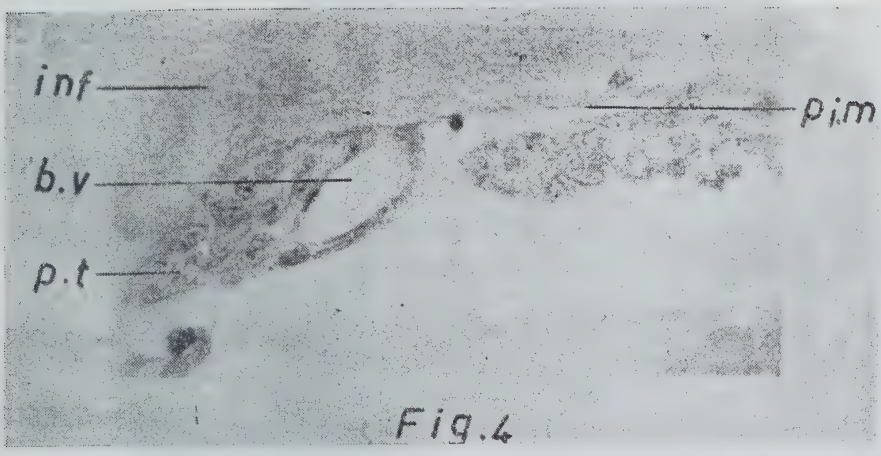

Fig. 4 *Photomicrograph of part of a longitudinal section of the pituitary gland of* Bufo regularis, *showing the pars tuberalis plastered to the infudibulum, which latter is separated from the glandular region by the pia mater connective tissue membrane*

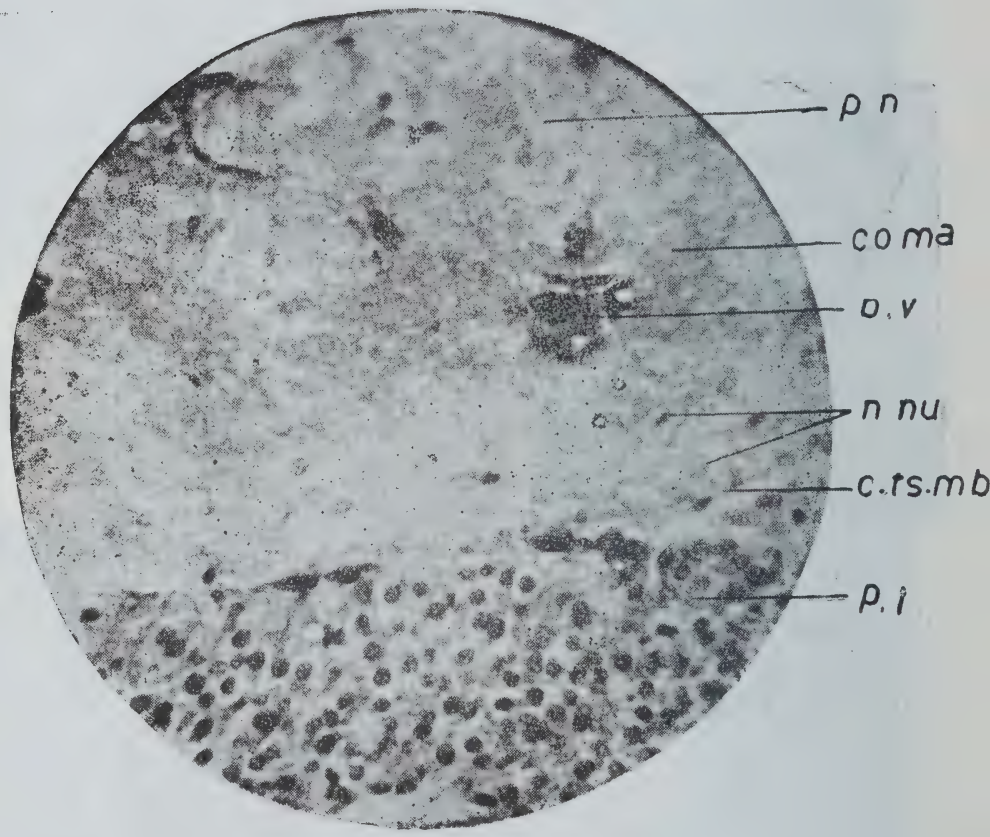

Fig. 6 Photomicrograph of part of a longitudinal section of the pituitary gland of Bufo regularis, *showing the pars intermedia and the pars nervosa. The latter contains blood vessels, neuroglia nuclei and colloidal material.*

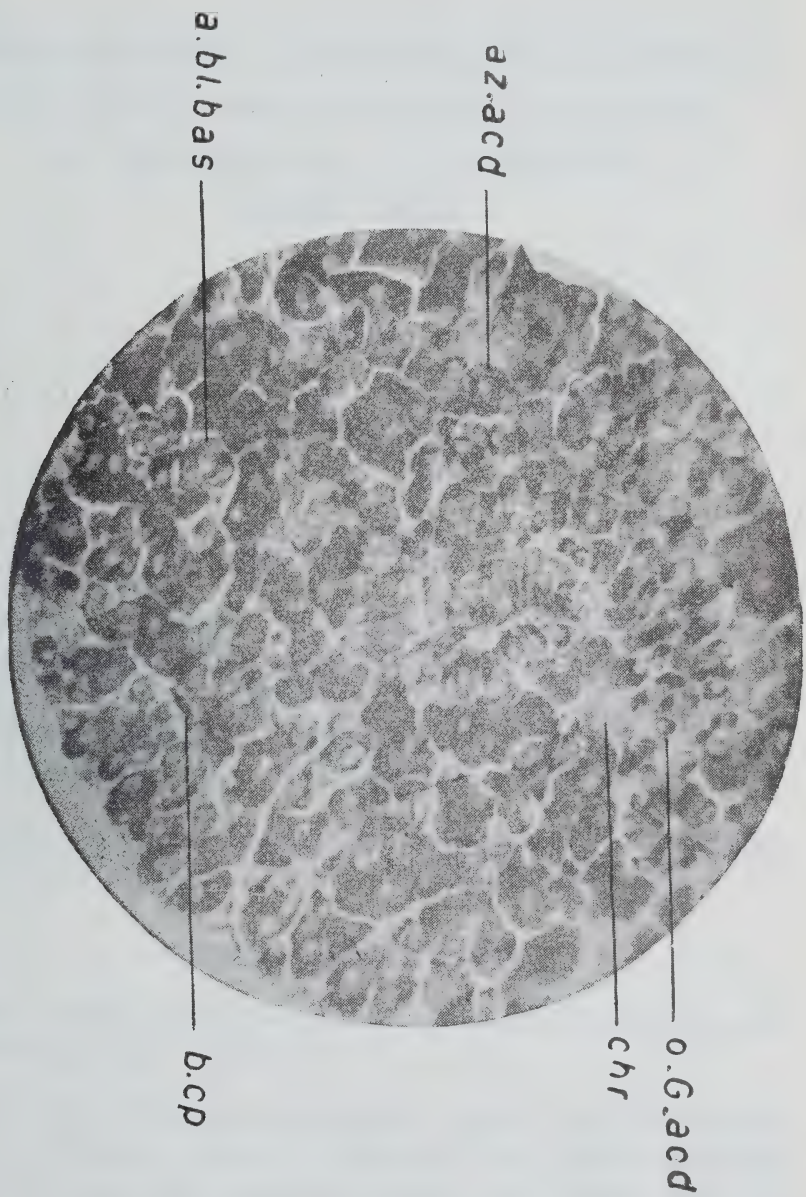

Fig. 6 *Photomicrograph of part of a longitudinal section of the pituitary gland of* Bufo regularis, *showing the azocarmine acidophils, orange G acidophils, chromophobes and anilin blue basophils in the pars distalis.*

HISTOCHEMICAL DEMONSTRATION OF SITES OF SUCCINIC DEHYDROGENASE ACTIVITY IN MITOCHONDRIA OF ANODONTA NERVE CELLS

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INTRODUCTION

The aim of this work is to find out by the histochemical tests the correlation between the succinic dehydrogenase and the mitochondria of Anodonta neurones. Shelton and Schneider (1952), Malaty and Bourne (1953), Portugalov and Yakovlev (1955, 1958) and others have studied biochemically the succinic dehydrogenase activity.

Since 1950 all the histochemical investigations of succinic dehydrogenase have been carried out by using the tetrazolium salts.

MATERIAL AND METHODS

The material used in this study consisted of the cerebral, pedal and visceral ganglia of Anodonta.

For demonstrating the mitochondria, Regaud's fluid was used and then the material was stained in Heidenhain's iron alum haematoxylin, The mitochondria were supravitally stained with Janus green. Th neotetrazolium (NT) reaction of Shelton and Schneider (1952) for demonstrating the succinic dehydrogenase activity was applied. Frozen

sections of fresh ganglia of 10—20 U were incubated for one hour at 37°C in a substrate consisting of :

One part of distilled water.

One part of 0.1 M Phosphate buffer pH (7.5).

One part of 0.1% of NT.

One part of 0.1 M sodium succinate.

The sections were then fixed in 10% formol saline for 10 minutes and mounted in glycerine.

OBSERVATIONS

The nerve cells in the ganglia of Anodonta are arranged around a central mass of nerve fibres and neuroglia.

Mitochondria, as revealed by Regaud's iron-alum heamatoxylin occurred in the form of granules and few rods scattered throughout the cytoplasm (Fig. 1). A similar picture of mitochondria was given in material supravitally stained with Janus green. In supravitally stained material numerous refringent fat globules were detected.

The neoterazolium salts (NT) are reduced by the effect of succinic dehydrogenase giving rise to two different reduction products, a blue product which is the diformazon and the red product which is the monoformazan. The site of activity of succinic dehydrogenase was demonstrated as numerous granules and few rods which are slightly larger than the mitochondria and are scattered through the whole cytoplasm (Fig.2). This throws some light on the question of the relation (in position) between the enzyme and the mitochondria. The nuclei are devoid of the succinic dehydrogenase. The site of activity of the enzyme (Formazan precipitate) is demonstrated in the axons of the neurones (Figs. 2 and3). In the different types of neurones of the ganglia there is only noticeable differenee in the site of activity of succinic dehydrogenase, this is due to the difference in activity of the different neurones. The number and distribution of these bodies (Formazan precipitate) are comparable with those of the

mitochondria. The lipid substances are stained with the tetrazolium salts and take an orange colour and the site of activity of the succinic dehydrogenase is distributed between these orange bodies (Figs 2 aud 3).

DISCUSSION

Succinic dehydrogenase is an important member of the battery of enzymes atached to the mitochondria which has drawn the attention of many biochemists and histochemist. Portugalov and Yakovlev (1955, 1958) studied the distribution of succinic dehydrogenase in the neurones of the cat and found that the site of activity of the enzyme was concentrated in the cytoplasm and not in the nucleus. Moussa and Khattab (1962), working on the neurones of the chick, support Portugalov that the enzyme is concentrated in the cytoplasm and that the nucleus is devoid of the enzyme. Torshinski (1958) found that the succinic dehydrogenase activity is localized in the cytoplasm and dendrites of the sheep neurones. While the activity of the enzyme in the neurones of Anodonta is concentrated in the cytoplasm and in the axons. Portugalov and Yakovlev (1958) found that the activity of the enzyme is high in the motor cells of the spinal cord of the cat, while in the neurones of Anodonta thers is no remarkable difference in the activity between the large and small neurones. In general, there is a small difference in activity between the neurones of the same type and this is due to the defference in the metabolic activity among the neurones. This may be explained on the grounds that Anodonta is a slow moving animal. Paydkula (1952), working on the muscles, Portugalov and Yakovlev (1955, 1958) on the neurones of the cat, and Moussa and Khattab (1962) on the neurones of the chick found that the succinic dehydrogenase represents a high concentration in that part of organ which represnts a high metabolic activity and that the site of activity is weak in the cells which are not metabolically active. the In present study the formazan distribution in the neurones of Anodonta corresponds to the distribution of the mitochondria. This agrees with the biochemical date of succinic dehydrogenase, as revealed by the fractional centrifugation, that the precipitate of formazan is united with the

mithochondria and that the ferment is localized inside the mitochondria or adsorbed on to it, (Hogeboom and Schneider, 1952. Malaty and Bourno, 1953, Wachstein and Meisel, 1955 and Nachmias and Padykula 1958).

The biochemical data and the present work on the histochemisery of the succinic dehydrogenase activity indicate that the formazan precipitate, arrangment and distribution throughout the cytoplasm correspond to that of the mitochondria. Concerning the localization of the enzyme the present writer is inclined to believe that the enzyme is localized inside the mitocondria.

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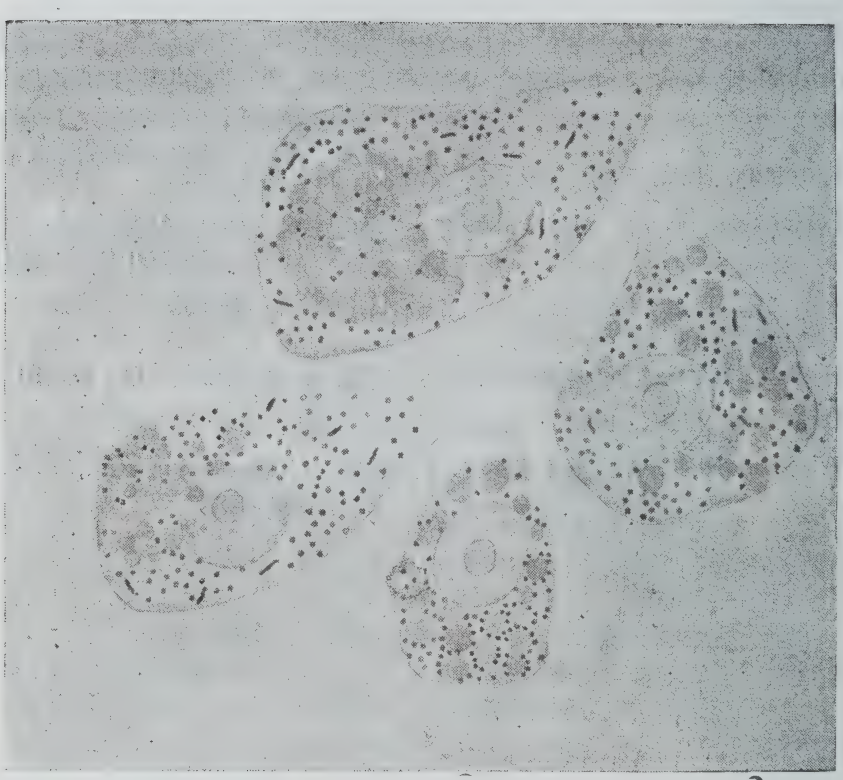

Fig. 1. *Neurones of Anodonta stained in Heidenhain's iron alum hcamatoxylin showing the mitochondria and the lipid substance*

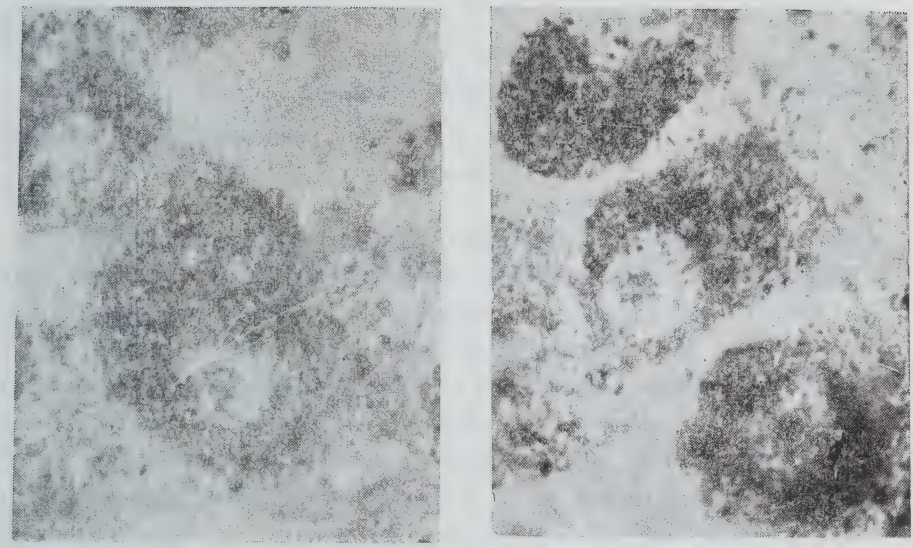

Fig. 2. Two photomicrographs of Anodonta eurones showing the siten activity of succinic dehydrogenase.

CHEMICAL STUDIES ON KAOLIN TREATED HUMAN PLASMA.

by

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The clarification of plasma by filtration is a difficult procedure, since plasma tends to clot during the process, and the resulting product is liable to instability. Macfarlane, MacSween, Mainwaring, and Parish (1942) describe a method of rapid filtration desingned to overcome this difficulty, in which only a very limited amount of plasma is allowed to pass through each pad. Even so, either the method is going to be very extravagant in pads, or much trouble with delayed clotting (after filtration) will be encountered. These states of affairs become more marked if the filtered plasma is kept in the cold or is subjected to transportation. On account of the unsatisfactory nature of this procedure, Bushby, Buttle and Whitby (1940) introduced 'the alkali wash' method, in which the pads are repeatedly backwashed with alkali during the filtration process. This method undoubtedly eliminated the problem of the plasma clotting during filtration, but it was clumsy to operate, and if, after washing through the filter, the plasma was collected too soon, serious dilution occurred; if too late, there was a serious wastage of plasma. Bushby and Whitby (1942) then introduced the 'alkali' process in which the pH of the plasma was adjusted to the region of pH 11 before filtration, and was subsequehtly brought back to normal by bubbling carbon dioxide through it. Again, this method

avoided filtration clotting of plasma and was mach easier to carry out than the 'alkali wash' method; on the other hand the filtration efficiency of asbestos pads at pH 11 is not high, and moreover, the process did not seem to be without adveres effects on the proteins.

Maizels (1944), by the introduction of the kaolin process for the filtration of plasma, has overcome nearly all these difficulties. The principle of this method is that the fibrinogen is absorbed out of the plasma by the kaolin, so that a fibrinogen free plasma results, which will not clot on filtration. In other words the plama is converted into serum without actual clotting or the introduction of calcium. Clegg and Dible (1940) had used the method of adding calcium to clot citrated plasma, thus rendering it easy to filter, and on clinical trial this serum, made from calcified plasma, appeared to have no harmful effects. Experience with the clotting of citrated plasma by adding calcium, proved that the calcium could be reduced to a low level, so that a jelly clot was formed and yet a good yield of serum could be obtained if the jelly clot was frozen and then allowed to thaw; under these conditions the clot contracted extremely satisfactorily and a good yield of serum resulted. However, when Maizels introduced the kaolin method, it was so obviously superior to the calcium method that the calcium method was completely abandoned.

The seitz filtration of the kaolinized plasma removes the anaphylatoxins generated in the plasma by shaking it up with kaolin, and such filtered plasma can be injected in large amounts intravenously into guinea-pigs without any ill effects. There is also some evidence that the kaolin process removes some of the pharmacologically active substances from plasma, and this is borne out clinically by the fact that the kaolin plasma seems remarkably free from all reactions.

The kaolin can be separted from the plasma by centrifugation, in which case about 18% of plasma is lost in the interestices of the kaolin deposit, and a further 6.8% is lost by adsorption of fibrinogen from the non-occluded plasma. If the kaolin is left for five days to settle, loss of plasma by occlusion is 17%. Analysis of kaolin treated plasma carried out by Maizels, showed that the calcium increased as

a result of kaolin treatment from 7.4 to 9.6 mg.%, while magnesium rose from 1.2 to 2.7 mg.%. The pH of plasma was unaffected by the addition of kaolin.

Maizels, did not go into further chemical details concerning the kaolin treated plasma. In this paper, are given the results of analysis of pH, total protein, non-protein nitrogen, polypeptide index, albumin globulin ratio, sodium and potassium concentrations of the plasma before and after kaolin treatment. In addition, chemical data relative to the aging of normal citrated plasma and kaolin treated liquid plasma are tabulated. The chemical changes of liquid pooled plasma stored at room temperature for six months do not appear to effect materially the usefulness of liquid plasma in the treatment of shock or hypoproteinemia. Our results dealing with the room-temperature stored normal plasma are compared with those reported by previous workers (Taylor et al, 1944).

METHODS.

Preparation of citrated plasma for room-temperature storage: Plasma was prepared from outdated blood (2 weeks or olde). It was separated from the sedimented red cell mass and then stored at room temperature. Each blood transfusion was drawn in A.C.D. anticoagulant solution containing 2.2 per cent trisodium citrate, 0.8 per cent citric acid and 2.45 per cent dextrose in pyrogen-free water (15 ml. A.C.D. solution for each 100 ml. blood). The blood was stored at refrigeration temperatures (4°C. to 6°C.) until transfused as such or converted to plasma, pooling generally with plasma from ten donors. The plasma was then syphoned into standard M.R.C. plasma transfusion bottles under aseptic conditions. This plasma was stored at room temperature without preservatives in a place protected from direct sunlight. The plasma was prepared in a laboratory located in the same building as the donor center. The temperature of the room in which the plasma was stored was recorded daily. Temperatures recorded during the period of storage varied from 14°C. to 34°C. During room temperature storage, monthly samples were taken for sterility control and for chemical analysis.

Processing of citrated plasma with kaolin : Colloidal kaolin (Leather Trades Specification) was placed in a 2-litre plasma Winchester (200 g./2 litre of pooled plasma), 10 ml. of saline was then added, and the whole sterilized by autoclaving at 20 lb./sq. in. for one hour. The plasma was then transferred from the pooling Winchester bottle straight on to the kaolin, left at 2°C. for a day, shaken again and then left for a further 5 days to settle. The plasma was then syphoned into standard M.R.C. plasma transfusion bottles under aseptic conditions. Samples of pooled plasma were drawn from each Winchester before and after mixing with kaolin, for sterility control and chemical analysis. The plasma bottlrs were then left to stand at room temperaiure for six months in a place protected from direct sunlight, as in the previous set of experiments. During room temperature storage. monthly samples were taken for sterility control and for chemical analysis.

Sterility control : The neck and cap of the M.R.C. plasma bottle were flamed, and 1 ml. sample was inoculated into 5 ml. of molten agar (45°C. to 48°C.). The agar bottles were then sloped on a glass rod and left to solidify at room temperature for 3 days, then incubated for 4 days at 37°C. The tests were read and infected bottles were discarded.

During room temperature storage of the plasma, the following two tests were carried out at monthly intervals. Under sterile conditions 10 ml. of plasma was drawn from the M.R.C. bottle and inoculated into 50 ml. of each of the following two media: (1) Broth and (2) Brewer's. Both tests were incubated for 3 days at room temperature and 4 days at 37°C. The tests were read and the infected bottles were discarded.

Calcium clotting time (Method of Biggs and Macfarlane) : To 0.1 ml. of citrated plasma was added 0.1. ml. of 0.85 per cent saline. the tube was placed in a water bath at 37°C. and 0.1 ml. of M/40 calcium chloride was added. A stop watch was started as the calcium chloride was added and the time for coagulation to occur was recorded. With normal plasma the clotting time yaries from 90 to 250 seeonds.

Chemical studies :

Estimation of the plasma pH was made by the glass electrode technique, total plasma protein and non-protein nitrogen by micro-Kjeldahl. The polypeptide index was determined by the method of of Hiller and Van Slyke (1922). In this method. the difference between the nitrogen content of the 2 5 per cent trichloroacetic acid filtrate and that of the tungstic acid filtrate is an index of the polypeptide content of the plasma.

Determination of albumin-globulin ratio by paper electrophoresis
The determination of albumin-globulin ratio was carried out on serum prepared by adding calcium to clot citrated plasma (Clegg and Dible, 1940). The jelly clot was frozen and then allowed to thaw. Under these conditions, the clot contracted extremely satisfactorily and a good yield of serum resulted using 1 ml. portions of the plasma. The removal of fibrinogen by this method was found necessary, since it has been demonstrated that the affinity of azocarmine - B to combine with fibrinogen is more than its affinty to combine with the other major fractions of plasma proteins, on molecular weight basis. All specimens of citrated plasma which have lost their clotting factors, were also treared in a similar manner.

Paper electrophoresis was carried out on Whatman no. 1 paper strips 6 x 52 cm. The paper was saturated with barbital buffer pH 8.6, ionic strength 0.1, and allowed to drain in position in the cell for 15 minutes. Serum prepared by the recalcification of the plasma (0.06 ml.) was then applied from a micropipette to the apex of the strip. Separation was carried out with a constant current; a tension of approximately 170 volts and temperature 25°C. gave after 16 hours a diagram of approximately 15 cm. length. After termination of the electrophoresis process, the paper strips were dried at 105°C in a drying box during 15 minutes. The strips were then transferred to a staining rack which holds them apart, and placed in a saturated solution of azocarmine-B in the following solvent system : methanol 500 ml. , glacial acetic acid 100 ml., and water up to 1000 ml.

The paper strips were put in this solution for 10 minutes, now and then balancing the vessel during this time. After filling a second perspex vessel with methanol, the paper strips were rinsed in this vessel, taking care that the vessel was continuously kept in motion. The methanol was refreshed at least twice during the process until the protein — free parts of the paper were practically white. Finally the paper strips were rinsed with 10% acetic acid; then dried at room temperature.

For the colorimetric determination of the albumin - globulin ratio, the strips were cut into their respective segments and eluted in 0.01 N sodium hydroxide for 30 minutes, with occasional agitation, thoroughly mixed and read within one hour in a Lumetron colorimeter at 530 mu., in 1.5 cm. cuvettes.

Determination of sodium and potassium : Sodium and potassium in the plasma were determined by flame photometry using a Beckman spectrophotometer, model DU aup Beckman flame photometer attachement (manufactured by Nationl Technical Laboratories. South Pasadena, California), according to the method described by Mosher et al (1949). The accuracy of this method depends on the use of synthetic standards in an effort to approximate the physical and chemical properties of the plasma samples to be tested. The viscosity of the standard solutions was made approximately equal to that of plasma by the addition of gelatin and cholestrol. Glucose, urea and all cations in concentrations approximating those of the samples to be analysed, were also included in the stock solutions in order to carry out the principle of approximating the chemical compositien of the sample, thus increasing the accuracy of the technique of flame phtometery when applied to the determination of sodium and potassium in plasma.

EXPERIMENTAL RESULTS.

Plasma proteins:

Over a period of six months, the changes in total plasma protein, non-protein nitrogen, polypeptide index and albumin-globulin ratio of

both normal and kaolin treated liquid plasma; are given in tables 1, 2, 3, and 4 respectively. In normal liquid plasma the total protein decreases from a normal value of 5.8 per cent to 5 per cent. This decrease in total protein is more marked in this set of experiments than in a similar set of experiments reported by Taylor et al (1944) in which glucose and merthiolate were added to liquid plasma for preservation. These authors reported an average decrease in total plasma protein from 6.6 per cent to 6.25 per cent in two plasma pools over the same period of storage. Processing with kaolin, on the other hand causes a marked drop in total plasma protein from a normal value of 6.2 per cent to 4.9 per cent. The total protein of kaolin treated liquid plasma decreases from an average value of 4.9 per cent to 4.5 per cent over the six months' period of room temperature storage. This decrease in total protein of both normal and kaolin treated liquid plasma, during room temperature storage, can be quantitatively accounted for in the sediment which forms at the bottom of the M.R.C. plasma bottles. The non-protein nitrogen of both normal and kaolin treated liquid plasma does not show significant alteration during the same period of storage.

The polypeptide index of normal liquid plasma rose from a normal value of 6.5 mg. per cent to appreximately 11 mg. per cent over the six months' period. This rise in polypeptide index may be attributed to the release of certain polypeptides as a result from the interaction between prothrombin and the active serum prothrombin conversion accelerator (SPCA) which is slowly formed from its precursor on storage of the plasma (seegers and Ware, 1949; Alexander and Landwehr, 1949). The results also indicate that processing with kaolin increases the polypeptide index of liquid plasma from an average value of 5.6 mg. per cent to 8.7 mg. per cent. This abrupt increase may he explained by the probable conversion of adsorbed prothrombin to active thrombin through the action of kaolin (Maizels, 1944). Like normal liquid plasma the polypeptide index of kaolin treated liquid plasma rises up to an average value of 12 mg. per cent over the six months' period of room temperature storage. In this connection, it may be interesting to note that Lorand (1951) has reported that in the clotting process, a non-protein reaction product is liberated from the fibrinogen during its

conversion to fibrin. The mass of this soluble product is 3 or 4 per cent of the total fibrinogen. The breakdown product, termed, fibrinopeptide by Lorand, is free of tyrosine and apparantly also of tryptophan.

The albumin globulin ratio of liquid plasma decreased from a normal value of 1.3 to approximately 1.1 over the six months' period of room temperature storage. Processing with kaolin, however, has no significant effect on the albumin-globulin ratio of the plasma, presumably because the major protein fractions of human plasma are adsorbed on kaolin to the same degree. Like normal plasma, the albumin-globulin ratio of kaolin treated liquid plasma decreases from an average value of 1.4 to 1.2 over the six month' period of room temperature storage. In this connection it may be important to note that Taylor et al (1944) reported no material changes in the distribution of albumin or globulin as determined by the method of Howe (1921) using sodium sulphate for fractionation. Electrophoretic studies of human plasma stored at room temperature (Hoch and Chanutin, 1954), showed that the fibrinogen was no longer distinguishable as a seperate peak after six to seven months. The albumin concentration did not change but its mobility increased slightly. Studies of the protein content of pooled plasma (calculated from electrophoretic patterns) stored ot room temperature for different periods of time (Allen et al, 1953) showed that the percentage of albumin expressed as percentage of total protein concentration, slightly increased in the 9th month (50.8 per cent after nine month as compared to 49.7 per cent after the second month). The decrease in the albumin-globulin ratio presented in table 4, may be attributed to different degrees of unfolding of the peptide chain of the plasma proteins, during room temperature storage, thus allowing access of the dye to relatively more dye binding sites in the more labile globulins. The same explanation has already been proposed by Jencks et al (1955) to account for the effect of the length of time of oven drying on the dye uptake of human serum albumin on paper.

Table I

Average values of measurements of total protein (grams per 100 ml.)* mabe on normal and kaolin treated liquid plasma, stored at room temperature over a period of six months (5 pools each).

Period of storage (months)	Normal liquid plasma	Kaolin treated liquid plasma
Before treatment	- -	6.2 ± 0.24
0**	5.8 ± 0.17	4.9 ± 0.23
1	5.55 ± 0.17	4.9 ± 0.17
2	5.05 ± 0.45	4.9 ± 0.17
3	4.8 ± 0.15	4.9 ± 0.25
4	4.9 ± 0.10	4.7 ± 0.15
5	5.1 ± 0.25	4.6 ± 0.25
6	5.0 ± 0.30	4.5 ± 0.19

* standard deviations are shown at the right of the averages.

** 0 – Baseline values.

Table II

Average values of measurements of non-protein nitrogen (mgm. per 100 ml.)* made on normal and kaolin treated liquid plasma stored at room temperature over a period of six months (5 pools each).

Period of storage (months)	Normal liquid plasma	Kaolin treated liquid plasma
Before treatment	- -	22.7 ± 3.1
0**	21.7 ± 1.4	21.7 ± 0.9
1	22.7 ± 1.3	21.0 ± 0.7
2	21.4 ± 3.9	22.9 ± 1.1
3	21.7 ± 0.4	22.9 ± 1.2
4	23.4 ± 2.0	22.9 ± 1.0
5	22.4 ± 2.0	22.9 ± 1.1
6	21.9 ± 2.4	22.9 ± 1.1

* Standard deviations are shown at right of the averages.

** 0 — Baseline values.

Table 3

Average values of measurements of polypeptide index (mgm. per 100 ml.)* made on normal and kaolin treated liquid plasma stored at room temperature over a period of six months (5 pools each).

Period of storage (months)	Normal liquid plasma	Kaolin treated liquid plasma
Before treatment	- -	5.6 ± 0.5
0**	6.5 ± 1.2	8.7 ± 0.3
1	6.9 ± 1.3	9.6 ± 2.2
2	7.7 ± 2.8	10.2 ± 1.6
3	8.0 ± 0.9	10.6 ± 3.0
4	8.9 ± 3.2	11.4 ± 4.2
5	10.8 ± 3.0	12.7 ± 2.4
6	11.3 ± 5.81	12.0 ± 2.5

* Standard deviations are shown at the right of the averages.

** 0 – Baseline values.

Table 4

Average values of measurements of albumin - globulin ratio* made on normal and kaolin treated liquid plasma stored at room temperature over a period of six months (5 pools each).

Period of storage (months)	Normal liquid plasma	Kaolin treated liquid plasma
Before treatment	- -	1.4 ± 0.20
0**	1.3 ± 0.12	1.4 ± 0.14
1	1.2 ± 0.1	1.4 ± 0.17
2	1.2 ± 0.1	1.3 ± 0.18
3	1.2 ± 0.1	1.3 ± 0 15
4	1.1 ± 0.1	1.3 ± 0.15
5	1.1 ± 0.1	1.2 ± 0.11
6	1.1 ± 0.07	1.2 ± 0.11

* Standard deviation are shown at the right of the averages.

** 0 – Baseline values.

Sodium

Plasma sodium was estimated in two pools before and after processing with kaolin. The results obtained show that kaolin treatment has no material effect on the sodium content of human plasma. The results also indicate that room temperature storage of the plasma in neutral glass (standard M.R.C. transfusion bottles) has no appreciable effect on the level of sodium in the plasma, during the first six months' period of storage. The results of analysis of the two plasma pools are given in table 5.

Table 5

Sodium content (mgm. per 100 ml.) of kaolin treated liquid plasma during the first six months' period of room temperature storage.

Period of storage (months)	Pool 243	Pool 249
Before kaolin treatment	400	292
0*	400	295
1	392	300
2	400	292
3	395	295
4	410	305
5	400	300
6	400	295

*0 – Baseline values.

Potassium :

It is well known that the potassium content of plasma gradually increases on standing in contact with red blood cells, a fact which explains the relatively high concentration of potassium in pooled plasma separated from stored banked blood (about 50 mg. per cent as compared to 16 — 22 mg. per cent in fresh plasma). The results listed in table 6 show that room temperature storage of normal and kaolin treated liquid plasma slightly increases the potassium content

of the plasma, a phenomenon which may be attributed to the desintegration of the few contaminating red cells present in the gravity separated plasma during the six months' period of storage. No significant alteration in the plasma potassium could be detected after kaolin treatment.

Table 6

Average values of measurments of potassium (mg. per 100 ml.)* made on normal and kaolin treated liquid plasma stored at room temperature over a period of six months (5 pools each):

Period of storage (months)	Normal liquid plasma	Kaolin treated liquid plasma
Before treatment	- -	51 ± 1.3
0**	49 ± 13.3	51 ± 3.6
1	53 ± 3.3	51 ± 4.6
2	53 ± 4.1	53 ± 2.8
3	52 ± 4.5	54 ± 4.9
4	52 ± 2.1	54 ± 6.6
5	57 ± 11	55 ± 7.3
6	57 ± 3.9	53 ± 5.3

* Standard deviations are shown at the right of the averages.

** 0 - Baseline values.

Miscellaneous :

As a test of the existence of complete coagulation mechanism, samples of normal and kaolin treated liquid plasma were recalcified. The normal plasma was incoagulable in 1 to 6 months ; while the kaolin treated plasma lost its clotting ability directly after processing with kaolin (table 7).

Contrary to the results reported by Taylor et al (1944) the pH of normal liquid plasma slightly decreased from a normal value of 7.05 to approximately 6.8 over the six months' period of room temperature storage. Processing with kaolin, on the other hand, caused a slight increase in pH (from 6.9 to 7.0). The pH of kaolin treated liquid plasma rose slightly from a normal value of 7.0 to approximately 7.2 over the six months period (table 8).

Cultures for bacterial groth were uniformly negative.

Table 7

Avcrage values of measurements of calcium clotting time (seconds) made on normal and kaolin treated liquid plasma stored at room temperature over a period of six months (5 pools each).

Period of storage (months)	Normal liquid plasma	Kaolin treated liquid plasma
Befor treatmant	– –	138
0*	198	No clot
1	6 minutes – 2 hours	No clot
2	No clot	No clot
3	No clot	No clot
4	No clot	No clot
5	No clot	No clot
6	No clot	No clot

* 0 – Baseline values.

Tabie 8

Average values of measurements of pH* made on normal and kaolin treated liquid plasma stored at room temperature over a period of six months (5 pools each).

Period of storage (months)	Normal liquid plasma	Kaolin treated lipuid plasma
Before trearment	– –	6.9 ± 0.2
0**	7.05 ± 0.17	7.0 ± 0.18
1	7.05 ± 0.32	7.1 ± 0.14
2	7.00 ± 0.1	7 2 ± 0.1
3	6.95 ± 0.1	7.25 ± 0.12
4	7.00 ± 0.24	7.3 ± 0.12
5	6.90 ± 0.1	7.3 ± 0.24
6	6 80 ± 0.16	7.2 ± 0.12

* Standard deviations are shown at the right of the averages.

** Beseline values.

DISCUSSION

Allen and co-workers (1950) have shown that the incidence of homologous serum jaundice is remarkably reduced if liquid plasma is stored for a number of months at room temperature before it is used for transfusions. These observations emphasize the necessity of obtaining information concerning the effect of storage on the plasma proteins. Earlier observations (Lozner and Newhouser, 1944, Taylor, Lozner, Davidson, Tagron, and Newhouser, 1944, Lozner, Taylor, Lemish, Snyder, and Newhouser. 1944, Tayeau, 1945, Polonovski, 1949, Macheboeuf, and Berger-Jeulin, 1950) have dealt with various changes in the chemical and physicochemical properties of liquid plasma on prolonged storage. Electrophoretic data on aging plasma are limited to random observations (Krejci, Sweeny and Sanigar, 1945, Scudder, 1940, Moore, Roberts, Castello and Schonberger, 1949, Ardry, 1951).

Moore and co-workers (1949) reported experiments which seem to indicate that changes which occur at room tempetature are mainly concerned with the lipid content of the serum, whereas the changes produced by more drastic temperatures would seem to depend upon the denaturation of theproteins. Similarly, Scudder (1940) found a decrease in the beta globulin/albumin ratio with samples that had been kept at room temperature.

The most labile of the plasma protein constituents appeared to be the clotting components. Prothrombin activity and fibrinogen disappear. Measurements of accelerator globulin and the antihemophilic globulin have shown that these substances rapidly deteriorate. Since plasma is used for the treatment of shock and not for treatment of abnormal beelding, loss of its clotting properties is considered clinically unimportant.

In addition, many of the above mentioned authors have reported two changes in the gross appearance of liquid plasma stored at room temperature, but which have proven of no clinical importance. Beginning two to twelve months after storage period, a gel appears which redissolves or lyses between the 18th to 36th month. This, in part at least, is fibrin-like. It is usually a fragile gel and seldom becomes

bulkly. It is readily removed by the usual filters employed in blood adminstration sets. A thin, powder-like white sediment also appears at the bottom of the bottles of liquid plasma and remains permanently. It is harmless and does not impair in any manner the adminstration of such plasma. Analysis of this sediment showed that it is similar in composition to the sediment which slowly forms in seitz filtered serum as it ages (Francis Harrison, and Picken, 1944). In the case of plasma, however, the nitrogen content of the sediment is higher, a fact which may be attributed to the clotting components which are readily denatured during room temperature storage. Colours range from a golden yellow to an opalescent green, these colors are best seen in the large pools, but are scarcely noticeable in the smaller 500 ml. units. The final product remains transparent, however, except for the thin gel and the small amount of white precipitate which is resuspended when agitated.

SUMMARY

1. Treatment of normal citrated plasma with kaolin, has nomarked effect on the sodium and potassium content of the plasma. The pH, non-protein nitrogen and albumin-globulin ratio do not show significant alterations as a result of kaolin treatment.

2. Processing with kaolin causes a marked decrease in the protein content of the plasma. One the other hand, the polypeptide index of the plasma significantly increases, a phenomenon which may be attributed to the splitting of certain polypeptides from the plasma prothrombin which is converted to thrombin as a result of the surface effect of kaolin.

3. Like normal plasma, room temperature storage of kaolin treated liquid plasma does not cause material changes in pH, non-protein nitrogen, sodium and potassium content of the plasma. As may be expected, the total protein decreases and the polypeptide index increases in both normal liquid plasma

and kaolin treated liquid plasma over the six months' period of room temperature storage. Contrary to electrophoretic determinations, of the albumin – globulin ratio of aging plasma by themoving boundary method; paper electrophoretic determination of this ratio, gave progressively decreasing values over the period of six months studied. The relative increase in dye uptake by the unfolding peptide chains of the more labile globulins, may explain this contraversy.

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EFFECT OF SOME CYTOTOXIC SUBSTANCES ON CHICK EMBRYOS.

By

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Introduction :

In another paper (Abd El Halim, 1963) it was found that quinones have the power of retarding or blocking the cleavage of the amphibian eggs. In this work another trial was done to investigate the effect of different types of quinones on the development of the chick in order to get new informations about the action of such quinones.

Material and technique:

The antimitotic substances used in the present study are I : 4 naphthoquinone, phenanthrenequinone and p-benzoquinone, which were supplied by the British drug houses Ltd. London. The experimental procedure of preparing the solutions was the same as that reported in the previous paper.

The newly laid eggs were incubated for 24 hours. Some of these eggs were left to act as a control. The others were injected with the substances mentioned above. The different concentrations used were I: 10^5, I: $5x10^4$ and I. $125x10^2$.

Injection was carried out as follows.—

A small hole was made into the shell. Then one ml. of the appropriate concentration of the substance in question was injected with a hypodermic needle. This injection was carried out into the albumen in the immediate neighbourhood of the blastoderm. After withdrawal of the injection needle, the hole was closed with wax. The eggs were

re-incubated for another 24 hours. Waddington and others (1955), used to leave the injected eggs for 24 hours at room temperature before re-incubation. But this procedure was not followed by the present author to avoid the damage which may happen to the eggs. These eggs were then opened and the embryos were stretched on slides, fixed in Bouin and stained with borax - carmine.

In this work one of the most effected embryos after being photographed was cut into serial sections of 10 microns in thickness. Some of these sections were stained with Heidenhain's iron haematoxylin and others with picro - indigo - carmine.

Results :

When $1 . 10^5$ concentration of the substance concerned was injected into the egg no effect was produced. All the eggs developed normally.

At $1.5x10^4$ concentration development of the embryos was retarted, where as at $1. 125x10^2$ no development took place.

At the effective concentration, a considerable variation from egg to egg was produced. This variation was probably due to the differences in the concentration of the substance actually reaching the blastoderm (Cf. Waddington and others, 1955).

1: 4 Naphtoquinone.

At $1.5x10^4$, different types of embryos were produced varying from the type shown in fig. 1 to that shown in fig. 5.

In fig. 1, the embryo was strongly retarded and distorted. Its nervous system appears as a thickened area and no distinction can be made between fore—, mid— and hind-brain.

The mesoderm as well as the primitive streack appear also as thicker and broader area than those of the control (Fig. 8). and no addditional somites were formed.

More over the two omphalomesenteric veins appear one on each side leading to the tubular heart which is now a single twisted tube. This condition resembles that of 37-hours stage. In other words the formation of the heart was slightly inhibited.

As shown in sections (Figs. 2, 3 & 4) it was found that the medullary plate has become a thickened flat plate which failed to close fnto a neural tube. In this case an extremely retarded platy-neuric embryo with a wide flat neural groove is formed (Fig. 1). Anteriorly the medullary plate was kept as a thickened flat plate while its lateral parts are folded inwards but they did not succeed in being united to form a closed neural tube (Fig. 2). In this case two lateral grooves were formed which may represent the two optic vesicles at such a stage in the normal conditions. This flattening of the medullary plate extends posteriorly down to the primitive streak. Some cells in the middle line of the medullary plate have sunk inwards forming a small tube which may represent a small neural tube in the anterior part of the embryo (Fig.3).

In the second embryo (Fig. 5) development was nearly the same as that of the control except in certain respects. The brain shows a stage which is similar to that of an embryo of 38 - hours of incubation. The fore-, mid- and hind-brain are still formed from neuromeres, whereas the two optic vesicles appear one on each side of the fore-brain. The development of the eye is also inhibited. The process of cranial flexion as well as that of torsion are also inhibited.

The heart remains as a twisted tube composed of atrium, ventricle and truncus arteriosus as it is in the case of the 40-hours stage.

Phenanthrenequinone :

This substance showed the following effects as shown in fig. 6 The longitudinal axis of the embryo remained straight, no flexion, and torsion took place.

The original eleven number, from which the three parts of the

brain are going to be formed, is still the same, a condition which is found in the 27 to 30-hours stage of incubation.

The mesoblastic somites become reduced in number. There are about 19 of them.

The development of the heart is also inhibited and it appears in the middle line i.e. not displaced to the right side as in the control (Fig. 8), a condition similar to that of 28 - 30 hours of incubation.

p-Benzoquinone :

This substance showed a slight effect on the embryos as shown in fig. 7.

The fore-brain shows two optic vesicles. The mid- and hind-brain are still formed of neuromeres. The neural tube extends posteriorly till the last posterior somite where the neural groove remains opened and the neural folds diverge to either side of Hensen's node.

Although torsion appeared in the anterior part yet cranial flexure did not take place due to the retardation of the development of the nervous system.

There are 23 mesoblastic somites and thus the formation of these somites is slightly retarded as the expected number is 25.

The tubular heart lies to the right side of the body of the embryo but it is not yet twisted on itself to form a loop which is the typical condition of the 48 hours stage.

Conclusion :

From the above results it could be concluded that the three quinones, 1:4 naphtoquinone, phenanthrenequinone, and p-bezoquinone have the effect of inhibiting the development of the chick embryos as in the amphibian ones (Waddington, 1958). The most effected tissues by the three quinones are the nervous tissue and to a slight

effect the vascular and the mesodermal tissues. The effect was more pronounced by 1.4 naphthoquinone.

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Explanation of plates

Fig. 1. Photo· of chick embryo injected at 24 hours with one ml. of $1.5x10^4$, 1.4 naphthoquinone, re-incubated 24 hours.

Fig. 2. Transverse section through the chich embryo shown in Fig. 1. at its anterior region.

Fig. 3. Transverse section of the same embryo through the heart region. N.t; neural tube. Nch; Notochord.

Fig. 4. Transverse section of the same embryo through the middle trunk region.

Fig. 5. Photo. of chick embryo injected at 24 hours with one ml. of $1.5x10^4$, 1.4 naphthoquinone, re-incubated 24 hours.

Fig. 6. Photo. of chick embryo injected at 24 hours with one ml. of $1.5x10^4$ phenanthrenequinone, re-incubated 24 hours.

Fig. 7. Photo. of chick embryo injected at 24 hours with one ml. of $1.5x10^4$ p-benzoquinone, re-incubated 24 hours.

Fig. 8: Photo. of chick embryo (48 hours old) uninjected and left as a control.

Fig. 1

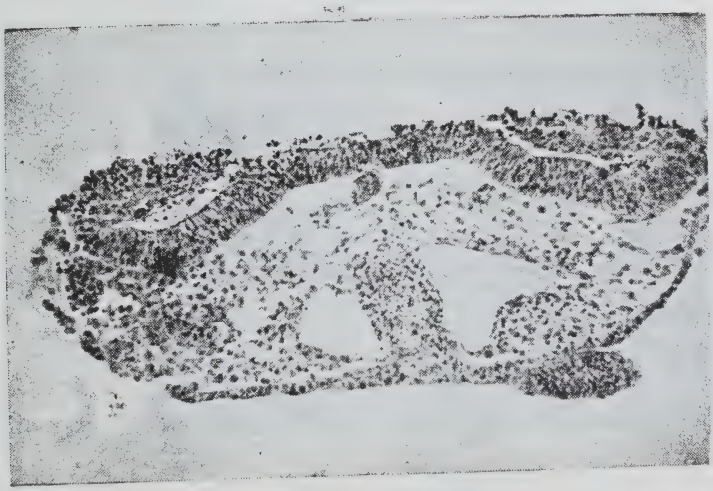

Fig. 2

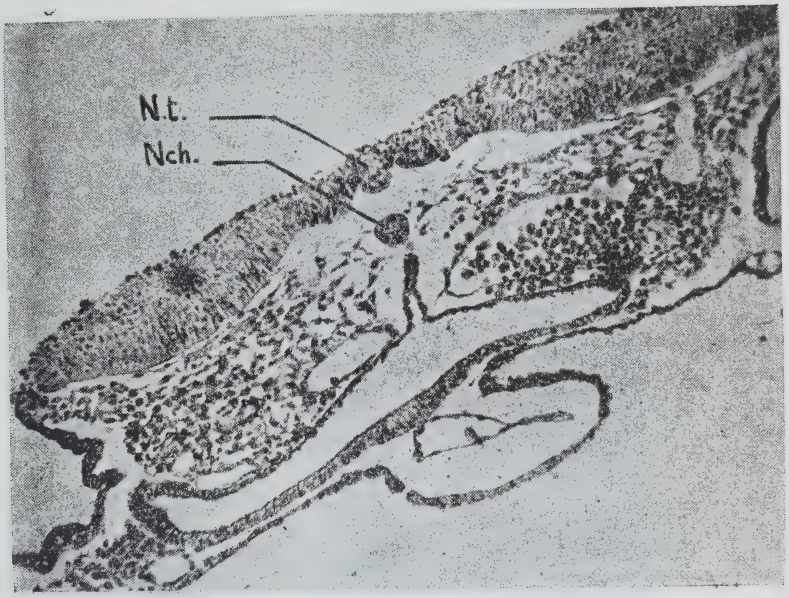

Fig. 3

Fig. 4

Fig. 5

Fig. 6

Fig 7

Fig. 8

REMOVAL OF THE EGG MEMBRANES OF THE COMMON EGYPTIAN TOAD, BUFO REGULARIS REUS BY MEANS OF PROTEOLYTIC ENZYMES

by

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Introduction :

Amphibian eggs are generally surrounded by jelly membranes in addition to the vitelline membranes. Several functions are attributed to these membranes viz, protection of the eggs against injury, against injestion by larger organisms, and from fungus and bacterial infections. It was also presumed that the jelly acts as an insulater against heat loss, thus helping in retaining the metabolically derived heat of the eggs. It was thought once, that the jelly acts as a lens, concentrating the heat rays of the sun onto the eggs, but Rugh (1951) considered this theory untenable since the jelly, being largely water, is a non-conducter of heat rays.

These functions are, however, presumably attributed to the jelly membranes without direct experimental evidence which would be brought forwards only when eggs were left to develop under various controlled conditions after removing their membranes. For this reason and also for experimental purposes it was found necessary to find out a method for the removal of these jelly mempranes. Several methods were recommended for this purpose which may be either mechanical, physical or chemical (Rugh 1948 ; p. 15). As a matter of fact all these methods affect the developing embryo by extensive mechanical and chemical injuries. Recently, other methods have been adopted which depend on biochemical dissolution of these membranes. Spiegel (1951) dissolved the two outer layers of the gelationous coat enveloping the eggs of **Rana pipiens** after a period of 1—2 hours treatment with a

2% solution of papain activated with cysteine-HCl at pH 6.6 - 6.8. The innermest jelly capsule and the vitelline mambranes were then removed by a 2.5% solution of thioglycolate at pH 8.1. Similar double treatments were found necessary to remove the fertilization membrane of sea urchins and dog salmon eggs. For the former species Monroy and Runnstrom (1948) found that the fertilization membrane was not attacked by trypsin alone, but could be dissolved by a double treatment of thioglycolic acid and trypsin. For the latter Kanoh and Yamamoto (1957) showed that single treatment with proteolytic enzymes was not sufficient to remove the egg membrane and concluded that a previous treatment with acid solution was necessary to attain enzymatic dissolution. Membranes of other vertebrate eggs are, however, dissolved by single enzymatic treatment viz, pancreatin or trypsin for the egg membranes of **Oryzias lotipes** (Ishida, 1914), pepsin for that of **Lampetra japonica** (Yamamoto, 1956).

In the present investigation some different kinds of proteolytic enzymes were employed in order to find a method for removing the egg membranes of the Egyptian toad **Bufe regularis** Reuss, a process which did not attract any investigator up till now.

Material and method :

Breeding of the female toads was induced by injection with anuran pituitary glands into the body cavity (6 female pituitaries and 3 male ones). This dose induced breeding within 8 - 10 hours after injection at 28 - 30°C. (vide Rugh, 1948).

Four commercial preparations namely, pepsin (Bayer), trypsin (B.D.H.), pancreatin (B.D.H.) and papain (Merk) were used in this investigation. For the last enzyme cysteine-HCl, glutathione, KCN and thioglycolic acid were used as activators. Before use the action of these enzymes was investigated qualitatively by the gelatin plate method of Pickford and Dorris (1934) and their action on the egg membranes was examined under a binocular.

Results :

Experiment I.

In a preliminary experiment we tried to test the effect of the four endopeptidases under consideration on the egg membranes. Two grams of each enzyme preparation were extracted with amphibian Ringer solution, the pH of which was adjusted to 2.5 for pepsin, 8.0 for trypsin, 7.0 for pancreatin and 5.5 for papain. The pH was adjusted by means of 0.01 N NaOH or HCl and was estimated by B.D.H. capillators. Extraction took place in the refrigerator overnight at 4°C and toluene was added as antiseptic. Before use 60 mg cysteine-HCl were added to the clear papain solution and the pH was readjusted to 5.5. Two cc. of the clear enzyme solution were poured in an embryo dish and a ribbon containing ten eggs was immersed in the enzyme solution. Incubation took place at room temperature 28-32°C. Control experiments were carried out at the same time in which similar egg ribbons were placed in a series of ombryo dishes containing Ringer solution at different H ion concentrations as those employed in the experiment

The results of this experiment showed that a complete dissolution of the egg membranes took place with papain-cysteine HCl after 40 minutes from the time of immersion. Pepsin, trypsin, as well as pancreatin showed negative results even after three hours incubation. Observations after 24 hours showed, howevsr, a complete attack by pepsin while the other enzyme solutions still showing negative reaction. The control experiments showed also that the Ringer solution at the different pH values employed in the experiment dose not bring about any dissolution of the egg membranes.

Experiment II.

In this experiment we tried to test the effect of pH on the digestion of egg membranes by means of papain-cysteine-HCl. The procedure was similar to that in experiment 1 : the results of this experiment are presented in Table 1 from which it could be seen that the optinal digestion took place at pH 8.0.

Table 1

Digestion of egg membranes of **Bufe** by papain-cysteine-HCl at different H ion concentrations.

Solution	pH	Digestion	Time of complete dissolution
Papain — cysteine — HCl	3.5	—ve	—
,,	4.5	+ve (eggs destroyed)	60 minutes
,,	5.5	+ve	40 ,,
,,	6.5	+ve	30 ,,
,,	8.0	+ve	15 ,,
Papain	8.0	—ve	—
Ringer	8.0	—ve	—
Ringer + Cysteine — HCl	8.0	+ve	175 ,,

At this pH value neither papain alone nor amphibian Ringer solution could show any action on the egg membranes. However, a Ringer solution containing the activater cysteine-HCl at pH 8.0 affected the hydrolytic splitting of the egg membranes after about three hours. This result points to a fact that the membranes are charged with the tissue enzyme cathepsin which awaits a suitable activater to start its action.

Experiment III.

As the plant enzyme papain is known to be a mixture of enzymes (Smith, 1951) for which glutathione, KCN and thioglycolate are activators, it was found reasonable to test the effect of this enzyme when mixed with these activators at different H ion concentrations on the digestion of egg membranes of toads. 2% extract of papain to which was added 8.0 mg glutathione, 10.0 mg KCN or 1.0 cc. thioglycolic acid at different pH values were used in this investigation. The results are presented in table II.

Table II

Digestion of egg membranes **Bufo** by papain and different activators at different **H** ion concentratious.

Solution	pH	Digestion	Time of complete dissolution
Papain + glutathione	3.5	—ve	—
,,	4.5	+ve (eggs destroyed)	120 minutes
,,	5.5	+ve	140 ,,
,,	6.5	+ve	180 ,,
,,	8.0	+ve	240 ,,
Papain	4.5	—ve	—
Ringer	4.5	—ve	—
Glutathione	4.5	—ve (jelly contracted)	—
,,	8.0	+ve (eggs swelled)	20 ,,
Papaln + KCN	3.5	—ve	—
,,	4.5	+ve (eggs destroyed)	330 ,,
,,	5.5	+ve	280 ,,
,,	6.5	+ve	120 ,,
,,	8.0	+ve	180 ,,
Papain	6.5	—ve	—
Pinger	6.5	—ve	—
KCN	6.5	—ve	—
KCN	8.0	—ve	—
Papain + thioglycolate	3.5	—ve	—
,,	4.5	+ve	40 ,,
,,	5.5	+ve	30 ,,
,,	6.5	+ve	8 ,,
,,	7.5	+ve	5 ,,
,,	8.0	+ve	8 ,,
Papain	7.5	—ve	—
Thioglycolate	7.5	—ve	—
,,	8.0	—ve	—

In Table II from which it could be seen that the time of dissolution as well as the optimal pH values differ for the different activators.

With papain-glutathione the optimal action took place after 120 minutes at pH 4.5. However, under these experimental conditions the eggs themselves underwent dissolution also.

Papain activated by KCN showed optimal action after 120 minutes also but at pH 6.5. At pH 4.5 the eggs were destroyed.

The most rapid action was obtained when papain was activated with thioglycolic acid. At pH 7.5 a period of five minutes was found sufficient to ensure complete dissolution of the envelopes of toad eggs.

Control experiments at the different pH optima obtained showed that neither Ringer solution nor the activators had any effect on the dissolution of the egg membranes. At pH 8.0, however, Ringer-glutathione solution could dissolve the egg membranes within twenty minutes. This result lends support to the above mentioned suggestion that the egg membranes of toad contain cathepsin which can manifest itself at pH 8.0 only when a suitable activator is available. KCN as well as thioglycolate on the other hand failed to activate this tissue enzyme even when a period of five hours was used for incubation.

Experiment IV.

In this last experiment it was tried to investigate the effect of removal of egg membranes on the pevelopment of toad embryos. The envelopes of fertilized eggs were dissolved by the various digestive mixtures which proved successful for this purpose. After the dissolution was achieved the eggs were washed several times with Ringer solution, then transferred to suitable aquaria filled with pond water and were left to develop. 24 hours later the developing embryos were compared with control ones and the results of this examination are given in Table III. From this table it can be seen that the dissolution of the membranes by papain thioglycolate and cysteine-HCl show the least effect on the development of embryos. The use of papain-glutathione or papain-cysteine-HCl resulted in much abnormalities. Papain-KCN on the other hand caused the death of all the embryos and glutathione affected a rapid autolysis of the eggs.

Table III

Effect of removal of egg membranes of **Bufo** by different digestive mixtures on the development of embryos.

Solution	PH	Time of complete dissolution	% normal embryes
Papain - thioglycolate	7.5	5 minutes	85
Papain—cysteine—HCl	8.0	15 ,,	14
Cysteine—HCl	8.0	175 ,,	97
Papain—KCN	6.5	120 ,,	0
Papain—glutathione	5.5	140 ,,	63
Glutathione	8.0	20 ,,	0

In a furthsr experiment, ribbons of eggs as well as nacked eggs were left to develop in two separate aquaria each containing 100 cc. of Ringer solution to which was added 10 mg. KCN. In the first case the embryos developed normally, while in the second all died. This experiment proves the protective function of the jelly membrane against toxicity of KCN.

SUMMARY

1. The egg membranes of the common Egyptian toad have been dissolved by various digestive mixtures. It was found that a complete dissolution of egg membranes took place with papain-cysteine-HCl after 15 minutes at pH 8.0. Trypsin and pancreatin showed negative results but pepsin has an action after 24 hours. The most rapid action was effected by papain thioglycolate (5 minutes at pH 7.5).

2. The egg emebranes were found to contain the tissue enzyme cathepsin without natural activators.

3. The effect of digestive mixtures on the development of embryos was investigated. It was found that the dissolution of the membranes by cathepsin-cysteine-HCl and papain-thioglycolate show the least effect on the course of development of the embryos.

4. The protective function of the jelly membranes against chemical injury was proved experimentally.

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STUDIES ON THE TOTAL BODY LIPIDS OF THE DESERT MAMMAL JACULUS JACULUS

by

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Introduction

It is well known that fat is the chief reserve store of fuel for animals, and that complete combustion of 100 gm. of fat produces 108 gm. of water. Such facts led to the belief that fat reserves and diet rich in fat are particularly valuable for protection against desiccation. This contention would appear to be supported by the fact that animals which live in the desert have large reserves of fat. However, Mellanby (1948) claimed that the only advantage of fat over carbohydrate under similar conditions of desiccation, is that a similar weight of fat will have a higher calorific value and will give more water of metabolism than the same weight of carbohydrate and therefore desert animals store fat in their bodies because fat in the only food substance which animals can store in any quantities. On the other hand, Schmidt-Nielsen et al (1955) discussed the old statement that "the camel's hump contains the water reservoir", and they found that this statement has only a grain of trouth.

Rathbun and Nello Pace (1945) recorded sex differences in the total fat content when the animals were compared on a fat-free body basis ; female guinea pigs averaged 4.7% more fat than males. However,

total lipids showed individual variations varying between 1.5 and 35.8% of the body weight.

Deuel (1955) recorded that environment may play a role in determining the type and amount of fat laid down in the animal. Babineau and Page (1955) reported that rats exposed to cold have to draw on their fat stores during the first month of exposure but later replenished their energy reserves.

Material and methods

Animals used in the present work are the lesser Egyptian jerboas **Jaculus jaculus**. Four groups of animals were experimented on: normal ones, animals fed on dry barlely (water content 8 - 10%) for 10 days before experimention, others fed on soaked barley (water content 45—50%) for 10 days. The last group is animals deprived from food for 2 days.

Animals were killed by a blow on the head. Care was taken to avoid any bleeding. The abdominal cavity was opened quickly and the contents of different parts of the alimentary canal were removed. The urinary bladder was also emptied from urine if present. Animals were then dried in an oven at 103 ± 1°C for several days till a constant weight was attained (Heller and Smirk, 1932; Adolph, 1943; Benjamin, 1946 and Khalil and abdel Messeih, 1959 a). The dry body of the animal was ground, then put in tared extraction thimbles of Soxhlet apparatus for subsequent weighing. The contents of the thimble were sbjected to the lipid extration with ethyl ether in Soxhlet apparatus. 48 hours were found sufficient for complete extraction of the lipids soluble in ethyl ether. The fat was calculated in percent of dry weight.

Results

The deta for the total body lipid content in animals are tabulated in tables (1—8). Table (9) represents the average and ranges of the whole data previously mentioned.

Sex variations :

It is clear from table (9) that the average value of the total body lipid content of normal females is considerably higher than that of normal males captured in the cold season. The average values for females and males are 22.48 and 13.15% respectively. Other animals do not show significant sex difference in the lipid content, except the starved animals in which there are noticeable differences between females and males during the cold season. The females possess higher amounts of lipids (11.29%) than the males (7.43%).

The average values for normal animals of the hot season are 10.92 and 12.97% for the females and males respectively. In animals fed on dry barley, the average total lipid contents in the females and males are 11.01 and 11.99% respectively during the hot season, while the average values in the cold season are 11.29 and 11.51%. On the other hand, in soaked fed animals, these values are 14.98 and 12.60% in the hot season, and 15.40 and 13.84% in the cold season. In case of starved animals, during the hot season, the values are 6.70 and 6.48 for females and males respectively.

Effect of season :

It seems from table (9) that there is no noticeable variation in the total body lipid content of the experimented animals expect in normal and starved females, of which the individuals of the cold season possess higher amounts of lipids than those of the hot season. The values for the normal females are 22.48 and 10.92% and for the starved ones are 11.29 and 6.70% for the cold and the hot seasons respectively. In the normal males the average values of fat in the hot and cold seasons are 12.97 and 13.15% respectively. In animals fed on dry barley, these averages are 11.01 and 11.29% respectively in the females and 11.99 and 11.51% in the males. In animal fed on soaked barely, these values of the hot and cold seasons are 14.98 and 15.40% respectively for the females while for the males the values are 12.60 and 13.84%. The average values of lipids for starved males in the hot and cold seasons are 6.48 and 7.43 respectively.

Effect of diet :

One can draw from table (9) that the effect of diet on the total body lipid content is to be noted in the females fed on dry and soaked barley in the cold season. These females possess higher contents of lipids In the normal condition (22.48%) than those fed on dry barley (11.29) and soaked barley (15.40%). On the other hand there is a noticeable increase in the contents of lipids of the females fed on soaked barley in the hot season when compared with the normal ones: the values being 11.98 and 10.92%. Other than that, it seems that there is no significant effect of diet on the total body lipid content of the experimented animals.

Effect of starvation :

In all the starved animals, the total body lipid content decreased to a large extent as compared with the normal ones. This considerable decrease could be felt when considering the following values of the total body lipid content of the normal and starved animals respectively; these are 10.92 and 6.70% for the females in the hot season, 22.48 and 11.29% for the females in the cold season, 12.97 and 6.48 for the males in the hot season, and 13.15 and 7.43% for the males in the cold season. (table9).

Discussion

It is clear that in spite of the wide individual variations in the total body lipid contents of animals shown in the tables (1 — 8), yet the averages represented in table (9) show that the sex difference is appreciably noticeable in the cold season of which normal and starved females have higher total lipid content than the males. This finding agrees with that of Rathbun and Nello Pace (1945). However, this variation might be related to the physiology of sex, but it requires further investigation as we must take into consideration several sexual factors, such as the factors that help in the milk formation and its correlation with the stored body lipid in relation to the kind of diet.

Considering the effect of season on the total body lipid content, it seems that the total body lipid contents are not considerably affected by season with the exception of normal and starved females which possess a higher lipid content in the cold season.

As to the effect of diet, one may note that most of the groups of animals under experimentation showed a decrease in their body lipid contents on a dry barley diet, while on soaked diet most of the groups do not show a significant difference in the total lipid content, as compared to the normal animals.

In all starved animals, the total body lipid content decreased to a large extent as compared to the normal animals.

From these above findings, one may conclude that the consumption of the body lipids is higher in the dry-fed and starved animals indicating that under these conditions the body lipids might be considered as one of the sources which supply the body with water resulting from their oxidation, as well as that these lipids act as a fuel for energy particularly in the starved animals.

SUMMARY

The present work, on the desert mammal **Jaculus jaculus**, in different seasons and under different dietary conditions shows that the body lipids might be considered as one of the sources which supply the body with water (resulting from their oxidation), as well as these lipids act as a fuel for energy particularly in the starved animals.

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Table 1

Jaculus jaculus : Percentage of total body lipid content of normal females (ethyl ether soluble fraction, dry body).

In the hot season.

Month	Animal			Lab. condition		Total body lipid %
	w. gm.	L. gm.	B.T. °C	A. T. °C	R.H. %	
Jun., 59	36.7	10.8	37.8	31.0	45	10.79
	36.2	10.1	38.2	33.5	43	12.93
Jul., 59	34.6	9.2	39.8	33.5	37	6.94
	41.5	10.7	38.0	30.5	42	13.24
Aug., 58	48.1	11.0	39.0	33.5	47	6.24
Sep., 58	45.1	10.8	38.9	25.5	60	15.39
Average	40.4	10.4	38.6	31.3	46	10.92

In the cold season

Month	Animal			Lab. dondition		Total body lipid %
	wt. gm.	L. cm	B.T. °C	A.T. °C	R.H. %	
Dec., 58	47.7	11.5	34.5	19.0	68	33.49
Jan., 59	49.1	11.2	35.0	17.0	64	22.58
Feb., 59	45.8	10.8	36.3	11.5	84	20.46
Mar., 59	48.4	11.0	37.0	20.0	70	13.35
	48.6	10.8	37.0	20.0	70	17.51
Average	48.0	11.1	36.0	17.5	70	22.48

A.T. Atmospheric temperature
B.T. Body temperature
R.T. Relative humidity

Table 2.

Jaculus Jaculus : Percentage of total body lipid content of normal males (ethyl ether soluble fraction, dry body).

In the hot season.

Month	Animal			Lab. condition		Total body lipid
	Wt. gm.	L. cm.	B.T. °C	A.T. °C	R.H. %	%
Jun., 59	28.5	9.5	37.5	33.5	40	5.40
Jul., 59	40.1	10.3	39.4	33.5	53	15.86
	38.3	9.2	38.4	33.5	37	10.37
Aug., 58	41.6	10.5	38.9	33.0	47	16.55
	41.2	10.3	37.2	33.5	47	8.05
Sep., 58	39.2	10.5	39.5	25.8	60	21.15
	45.1	10.5	39.0	25.8	69	13.40
Average	38.4	10.1	37.1	31.1	51	12.97

In the cold season.

Month	Animal			Lab, condition		Total body lipid
	Wt. gm.	L. cm.	B.T. °C	A.T. °C	RH %	%
Dec., 58	35.4	11.5	33.0	19.0	68	6.26
	40.3	11.0	32.5	19.0	68	6.44
Jan., 59	35.2	11.0	35.5	17.0	64	6.26
	46.8	11.6	35.0	17.0	69	11.28
Feb. 59	44.9	10.7	36.3	11.5	84	27.41
	48.8	11.0	36.0	11.5	84	27.75
Mar., 59	40.1	11.2	36.0	20.0	70	6.65
Average	41.6	11.1	34.9	16.7	72	13.15

Table 3

Jaculus jaculus : Percentage of total body lipid content of females fed on dry barley (ethyl ether soluble fraction, dry body).

In the hot season.

Month	Animal			Lab. condition		Total body lipid
	Wt. gm.	L. cm.	B.T. °C	A.T. °C	R.H. %	%
Jun., 59	34.3	10.2	38.5	32.0	63	6.50
Jul., 58	33.4	8.5	–	27.2	60	11.48
Jul., 59	37.6	10.5	39.0	31.5	48	18.70
	42.5	10.7	38.5	31.5	48	16.19
Aug., 58	39.8	10.5	38.0	32.0	45	11.92
Sep., 58	28.8	9.8	38.5	27.0	58	3.68
	45.5	11.6	37.9	27.5	56	8.92
	39.8	10.7	38.0	27.5	56	10.66
Average	37.8	10.3	38.3	27.0	54	11.01

In the cold season

Month	Aminal			Lab. condition		Total body lipid
	Wt. gm.	L. cm.	B.T. °C	A.T. °C	R.H. %	%
Dec., 58	46.2	11.0	33.0	19.0	69	25.22
Jan., 59	39.4	10.5	—	14.0	84	5.83
	42.3	10.6	—	17.5	65	6.23
Feb., 59	40.9	11.5	34.0	17.0	71	9.96
Mar., 59	48.4	11.2	36.0	18.5	70	13.54
	36.5	11.0	36.0	18.5	70	6.92
Average	42.3	11.0	35.5	17.4	72	11.29

Table 4

Jaculus jaculus: Percentage of total body lipid content of males fed on dry barley (ethyl ether soluble fraction dry body).

In the hot season.

Month	Animal			Lab. condition		Total lipid
	Wt. gm.	L. cm.	B.T. °C	A.T. °C	R.H. %	%
Jun., 59	35.8	11.2	38.0	32.0	63	6.82
	29.3	9.3	39.0	32.0	63	16.96
Jul., 58	30.8	8.7	—	27.2	60	12.12
	25.6	8.7	—	27.2	60	6.08
Jul., 59	32.4	9.4	38.2	31.5	48	18.20
Aug., 58	34.3	9.8	—	32.0	48	16.46
	30.2	9.5	—	32.0	48	7.26
Average	31.1	9.5	38.4	30.6	56	11.99

In the cold season.

Month	Animal			Lab. condition		Total body lipid
	Wt. gm.	L. cm.	B.T. °C	A.T. °C	R.H. %	%
Dec., 58	43.1	10.5	29.0	16.0	81	6.99
	50.9	11.4	37.5	14.0	64	28.26
Jan., 59	35.7	10.0	26.0	14.2	82	6.91
Feb., 59	37.3	11.5	33.0	11.5	84	5.21
	38.5	10.9	33.5	17.0	82	9.28
Mar., 59	52.0	11.2	36.0	18.5	70	12.42
Average	42.9	10.9	32.5	15.2	77	11.51

Table (5)

Jaclulus jaculus : Percentage of total body lipid content of females fed on soaked barley (ethyl ether soluble fraction, dry body).

In the hot season.

Month	Animal			Lab condition		Total body lipid
	Wt. gm.	L. cm.	BT. °C	A.T. °C	R.H. %	
Jun. 59	43.8	11.2	37.4	33.0	32	7.68
	33.6	10.0	38.2	33.0	32	12.95
	41.5	10.5	38.3	33.0	32	20 08
Jul., 59	21.7	8.5	38.5	31.5	38	11.66
	38.5	10.2	39.2	32.0	34	19.74
Aug., 58	48.9	11.9	38.9	25.0	63	17.76
Average	37.3	10.2	38.4	31.3	39	14.98

In the cold season

Month	Animal			Lab. condition		Total body lipid %
	Wt. gm.	L. cm.	B.T. °C	A.T. °C	R.H. %	
Dec., 58	43.6	11.0	37.0	19.0	68	15.20
Jan., 59	48.6	11.2	35.6	11.0	84	12.04
Feb., 59	44.3	11.5	30.0	15.0	71	7.44
Mar., 59	42.9	10.8	33 0	18.0	78	14.16
	46.8	10.8	34 5	18.0	80	19.83
	50.7	11.2	33.5	18.0	80	23.68
Average	46.2	11.1	33.9	16.5	77	15.40

Table 6

Jaculus jaculus : Percentage of total body lipid content of males fed on soaked barley (ethyl ether soluble fraction, dry body).

In the hot season:

Month	Animal			Lab. condition		Total body lipid
	Wt. gm.	L. cm.	B.T. °C	A.T. °C	R.H. %	%
Jul., 58	37.2	10.5	38 0	32.0	37	11.22
	35.5	10.0	38 0	32.0	40	14.63
Jul., 59	38 0	10.1	39.3	31.5	61	20.71
	27.8	9.5	37.8	31.5	38	14.86
Aug., 58	41.9	10.5	38.4	29.5	42	7.68
Sep., 58	38 0	10.0	39.0	29.0	43	6.49
Average	36 4	10.1	38.4	30.9	44	12.60

In the cold season.

Month	Animal			Lab. condition		Total body lipid
	Wt. gm.	L. cm.	B.T. °C	A.T. °C	R.H. %	%
Dec., 58	49.3	11.2	37.0	19.0	68	21.66
	43.0	10.5	37.0	19.0	68	12.84
Jan., 59	39.7	11.2	—	17.0	69	19.61
Feb., 59	41.6	10.8	35.0	15.0	71	7.49
	41.5	10.5	34.0	15 0	71	7.62
Average	43.0	10.8	35 8	17.0	69	13.84

Table 7

Jaculus jaculus : Percentage of total body lipid content of starved females (ethyl ether soluble fraction, dry body)

In the hot season.

Month	Animal			Lab. condition		Total body lipid %
	Wt. gm.	L. cm.	B.T. °C	A.T. °C	R.H. %	
Jul., 58	43.7	11.2	37.2	27.0	73	7.51
Jul., 59	35.3	10.3	38.0	29.5	76	7.62
Aug., 58	40.1	11.3	35.1	32.5	47	4.21
	38.3	10.8	37.5	32.5	47	9.35
Sep., 58	43.7	10.7	36.0	23.0	56	5.05
	44.5	11.4	33.5	23.0	56	6.48
Average	40.9	11.0	36.2	27.9	59	6.70

In the cold season.

Month	Animal			Lab. condition		Total body lipid %
	Wt. gm.	L. cm.	B.T. °C	A.T. °C	R.H %	
Dec., 58	43.5	11.2	30.0	19.0	60	5.26
	46.7	11.0	25.0	19.0	60	6.02
Feb., 59	40.9	10.2	32.0	9.5	95	4.96
	45.1	10.5	36.2	16.0	84	12.39
	44.3	10.5	36.5	16.0	84	11.39
	46.3	10.5	34.0	16.0	84	14.12
Mar., 59	41.6	10.5	33.0	19.5	65	21.08
	51.3	10.7	37.5	19.5	65	25.11
Average	44.8	10.6	33.7	16.8	75	11.29

Table 8

Jaculus joculus : Percentage of total body lipid content of starved males (ethyl ether soluble fraction, dry body).

In the hot season.

Month	Animal			Lab. condition		Total body lipid %
	Wt. gm.	L. cm.	B.T. °C	A.T. °C	R.H. %	
Jun., 58	32.7	9.2	37.5	23.0	56	6.05
	45.5	11.0	38.0	23.0	56	4.95
Jul., 59	34.6	10.3	35.6	30.5	48	7.51
Aug., 58	38.2	10.0	35.2	32.0	47	6.96
Sep., 58	39.4	10.2	36.2	28.5	51	7.29
	36.2	10.5	34.5	28.5	51	6.12
Average	37.8	10.2	36.2	27.6	52	6.48

In the cold season.

Month	Animal			Lab. condition		Total body lipid %
	Wt. gm.	L. cm.	B.T. °C	A.T. °C	R.H. %	
Dec., 58	41.3	11.0	23.0	19.0	60	5.93
	41.6	10.5	33.0	15.0	79	5.67
	47.1	10.5	31.0	15.0	79	7.52
Jan., 59	40.1	10.5	—	12.0	86	6.06
Feb., 59	48.1	10.9	—	11.0	90	14.48
Mar., 59	39.6	10.5	27.0	19.0	65	4.92
Average	43.0	10.7	28.5	15.3	77	7.43

Table 9

Average and ranges of the percentage of total body lipid content of **Jaculus jaculus** (ethyl ether stluble fraction, dry body).

	No. of animals	Animal			Lab. cond		Total body lipid content °/₀		
		Wt. gm.	L. cm.	B.T. °C	A.T. °C	R.H. °/₀	Ranges Min.	max.	Average
N.H., Females	6	40.4	10.4	38 6	31.3	46	6.24 —	15.39	10.92
C., ,,	5	48 0	11.1	36.0	17.5	70	17.51 —	33.49	22.48
H., Males	7	38.4	10.1	37.1	31.1	51	5.40 —	21.15	12.97
C., ,,	7	41.6	11.1	34.9	16.7	72	6.26 —	27.75	13.15
D.,H., Females	8	37.8	10.3	38.3	27.0	54	3.68 —	18.70	11.01
C., ,,	6	42.3	11.0	35.5	17.4	72	5.83 —	25.22	11.29
H., Males	7	31.1	9.5	38.4	30.6	56	6.08 —	18.20	11.99
C., ,,	6	42.9	10.9	32.5	15.2	77	5.21 —	28.26	11.51
So., H., Females	6	37.2	10.2	38.4	31.3	39	7.68 —	20.08	14.98
C., ,,	6	46.2	11.1	33.9	16.5	77	7.44 —	23.68	15.40
H., Males	6	36.4	10.1	38.4	30.9	44	6.49 —	20.71	12.60
C., ,,	5	43.0	10.8	35.8	17.0	69	7.59 —	21.66	13.84
St ,H., Females	6	40.9	11.0	36.2	27.9	59	4.21 —	9.35	6.70
C., ,,	8	44.8	10.6	33.7	16.8	75	4.96 —	25.11	11.29
H, Males	6	37.8	10.2	36 2	27.6	52	4.95 —	7.51	6.48
C, ,,	6	43.0	10.7	28 5	15 3	77	4.92 —	14.48	7.43

C. : Cold season.

D. : Dry-fed animals.

H. : Hot season.

N. : Normal animals.

So. : Soaked-fed animals.

St. : Starved animals.

GROWTH REGULATORS AND DORMANCY OF APRICOT SEEDS

By

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Dormancy is a general phenomenon, shown by a variety of plant organs viz. seeds, buds, bulbs, corms, tubers, rhizomes ... etc. The close parallelism between the phenomena in the various types of plant organs suggests that the physiological basis of dormancy is similar in all of them. Hence any contribution to our understanding of dormancy in one specific type of plant organ is likely to have broad implication for the subject as a whole.

General reviews of the literature relating to dormancy have included those of Crocker (6), Porter (38), Evenari (19) (20) and Toole **et al.** (46) for seeds, and Doorenbos (17), Samish (40) and Vegis (49) for buds.

Many investigators are of the opinions that growth promoters may play a role in dormancy.

It has been suggested that dormancy is determined by the absence of growth-hormones from the tissues. Avery **et al.** (1) found that auxins first appear in the terminal buds of **Aesculus** and **Malus** about three weeks before the visible swelling of the buds and that the highest concentration was reached just before bud-burst. Bennet and Skoog (3) could not find any diffusible auxin in resting pear buds. They observed that auxin gradually appeared during chilling as the depth of dormancy decreased.

On the other hand, it has been suggested that excess of auxin may bring about dormancy and that its gradual decrease removes the

growth - inhibltion. Guthrie (2) prevented the sprouting of potato tubers in storage by application of naphthalene acetic acid. Denny (15) suggested that some rest breaking agents, e.g. ethylene chlorohydrin and thiourea, counteracted the supra optimal hormone concentration present in dormant buds and tubers. There is very little evidence, however, that normal dormancy is due to supraoptimal concentrations of naturally occurring hormones.

Recently several investigators are of the opinion that growth-inhibitors may be responsible for dormancy in plants.

Thornton (45) suggested that primary and secondary dormancy of seeds may be due to the accumulation of intermediate products from partial anaerobic respiration, acting as inhibitors. He stated that low temperature storage retards the accumulation of these inhibitory substances leading to the germination of seeds, while high temperature storage increases dormancy because the hydrolyzing system remains more active than the oxidizing one. Leggatt (34) is of the opinion that the accumulatian of alcohol and acetaldehyde in the dormont seeds may act as germination inhibitors.

Evenari (19) listed about 100 species of plants from which germination inhibitors have been isolated from seeds, fruits, buds, leaves and roots. He reviewed the subject of the germination inhibitors together with the possible theories on the subject.

Many authors (26, 27, 28, 29, 30, 31, 32, 42, 4, 33, 48, 5) correlate the dormancy of buds of some plants to the presence of certain growth-inhlbitors which greatly decrease or disappear as the buds emerge from the rest period.

Some workers have suggested that the emergence from and the onset of dormancy are determined by the interaction of both hormones and inhibitors. The breaking of dormancy occurs when the level of growth promoters is greater than that of growth inhibitors and vice versa for the onset of dormancy (2, 35, 4, 41, 50....)

Methods.

The present investigation deals with seeds of *Prunus armeniaca*

var. Baladi. The seeds used were havested from plants grown in the Botanical Garden of the Facutly of Science, Abbassia, Cairo.

Extraction :-

The plant material was ground to a powder in cold redistilled ethanol by an electric atomix. It was then extracted at O°c with redistilled ethyl alcohol, with three changes, over a period of 24 hours The ethanol fractions were filtered and combined. The filterate was evaporated at vacuum at abouf 20°c to a few ml. ready for paper chromatography

The residue of the plant material, after ethanol extraction, was extracted again with 50% aqueous ethanol at O°c., using two changes of the solvent. The combined fractions were filtered and distilled under vacuum at 30°c. to a few ml. ready for chromatography.

The first extract was referred to as alcohol extract, while the second one was referred to as aqueous one.

Both extracts were " strip-loaded " on Whatman No. 1 filter-paper and run by the " descending method " using 80 % aqueous isopropyl a cohol.

After development of the chromatograms, they were cut into ten portions and each portion was eluted overnight in distilled water at o°c in a small petri-dish. The activity of these fractions was assayed by means of coleoptile " straight-growth " method. Growth promotion and growth inhibition were determined by reference to the growth of control dishes containing filter paper taken from above the starting line of the chormatograms.

The chromatograms were examined for fluorescence by ultra-violet chromatolite lamp. They were also subjected to various colouring tests, where a strip of the chromatogram was sprayed with some chemical reagents. The colour was noticed before, during and after drying at about 50°c.

Changes of Growth Substances During Seed Development

Samples of **Prunus armeniaca** seeds, at four different stages of development, were collected. Their characteristics, are briefly shown in table (1).

Table 1

Characters of Prunus seeds and Fruits at Different Stages of Development

Character	Stage (1)	Stage (2)	Stage (3)	Stage (4)
1) Mean weight of fruit.	2.1 gm.	4.3 gm.	6.9 gm.	9.1 gm.
2) Fruit colour	deep green	green	green	yellowish
3) Mechanical structure of the endocarp	soft	slightly solid	solid	solid
4) Mean weight of one seed	0.4 gm.	0.5 gm.	0.68 gm.	0.91 gm.

Stage (4) represents the mature freshly harvested seeds. The samples of the different stages were extracted by alcohol and water as described before. The extracts were simultaneously loaded and developed on different chromatograms using 80% isopropyl alcohol as a running solvent. The amount of extract loaded on each chromatogram was equivalent to that obtained from 2 gm. dry weight of seeds.

The chromatograms were simultaneously assayed by the straight growth method using **Hordeum** coleoptile sections.

The results of the alcohol fractions are shown in Figs. (1) and (2), while those of the aqueous fractions are represented in Figs. (3) and (4).

Results:-

It is clear that, there is one promoting zone and another inhibiting one in the alcohol extracts of **Prunus** seeds during development. The promoting zone has an RF ranging between 0.1 and 0.4, while the inhibiting zone has an RF ranging between 0.5 and 0.8. There is no significant change in the activity of the promoting zone during the different stages of seed development. The activity of the inhibiting zone, on the other hand, shows a gradual increase and reaches its maximum when the seeds become fully mature (stage (4).

In the aqueous extracts, on the other hand, there are some zones of promotion and one zone of inhibition (Fig 3, stage 1). The activity of the promoting substances shows slight changes during seed development, while that of the inhibiting substances increase gradually during this process.

The significance of these results will be discussed later.

Dormancy of Prunus armeniaca Seed

1) Germination of Freshly Harvested Prunus Seeds.

Many seeds are known to show a certain period of dormancy directly after their harvest. The following experiment was carried out to demonstrate the dormancy of freshly harvested **Prunus** seeds.

Chemical Tests for Alcohol Extracts of Prunus Seeds at Different Stages of Development.

Stage (1). (Fig. 1. Upper)

1)	**Ehrlish's reagent.**	RF 0.2-0.4 red colour.
		RF 0.79-0.86 violet colour.
2)	**Ferric/Perchloric.**	— ve.
3)	**Nitrous/Nitric.**	RF 0.56-0.68 yellow colour.
4)	**Ethanolic Fe cl_3.**	RF 0.53-0.68 green.
5)	**Iodine solution.**	RF 0.53-0.68 colour reduced.
		RF 0.87-0.95 colour reduced.
6)	**Potassium permanganate.**	RF 0.53-0.68 colour reduced.
		RF 0.87-0.95 colour reduced.
7)	**Ninhydrin.**	RF 0.53 0.68 yellow colour.

Stage (2). (Fig. 1 Lower)

1)	**Ehrlish's reagent.**	RF 0.22-0.45 red colour.
		RF 0.8-0.88 faint violet colour.
2)	**Ferric/Perchloric.**	— ve.
3)	**Nitrous/Nitric.**	RF 0.55-0.63 yellowish colour.
4)	**Ethanolic Fe cl_3.**	RF 0.55-0.68 green.
5)	**Iodine solution.**	RF 0.53-0.68 colour reduced.
		RF 0.88-0.93 colour reduced.
6)	**Potassium permanganate.**	RF 0.53-0.68 colour reduced.
		RF 0.88-0.93 colour reduced.
7)	**Ninhydrin.**	RF 0.55-0.7 yellow colour.

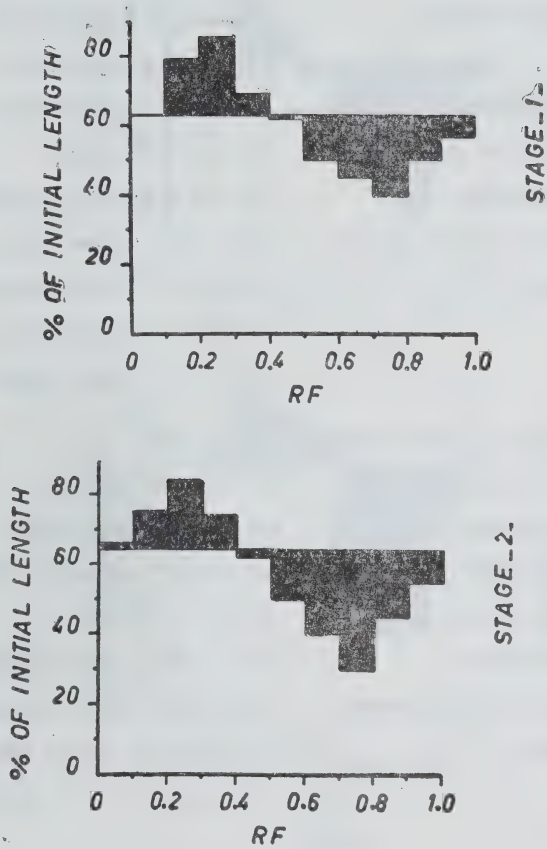

% OF INITIAL LENGTH
80
60
40
20
0
0
0.2
0.4
0.6
0.8
1.0
RF
STAGE-1
% OF INITIAL LENGTH
80
60
40
20
0
0
0.2
0.4
0.6
0.8
1.0
RF
STAGE-2

Fig. 1

Stage (3). (Fig. 2. Upper)

1)	**Ehrlish's reagent.**	RF 0.2-0.4 red changed into violet.
		RF 0.4-0.7 red colour.
2)	**Ferric/Perchloric.**	RF 0.2-0.4 yellowish red colour.
		RF 0.4 0.7 red colour.
3)	**Nitrous/Nitric.**	RF 0.4-0.7 yellowish red.
4)	**Ethanolic Fe cl_3.**	RF 0.4-0.7 green.
5)	**Iodine solution.**	RF 0.4-0.7 colour reduced.
6)	**Potassium permanganate.**	RF 0.4-0.7 colour reduced
7)	**Ninhydrln.**	RF 0.0-0.1 violet colour.
		RF 0.24-0.7 yellowish colour.
		RF 0 7-0.9 violet colour.

Stage (4). (Dry Fresh seeds) (Fig. 2. Lower)

1)	**Fhrlish's reagent.**	RF 0.4-0.8 red.
2)	**Ferric/Perchloric.**	RF 0.4-0.8 pale red.
3)	**Nitrous/Nitric.**	RF 0.4-0.7 yellowish colour.
4)	**Ethanolic Fe cl_3**	— ve.
5)	**Iodine solution.**	RF 0.4-0.8 colour reduced.
6)	**Potassium permanganate.**	RF 0.4-08 colour reduced.
7)	**Ninhydrin.**	RF 0.0-0.25 violet colour.
		RF 0.5-0.6 violet colour.

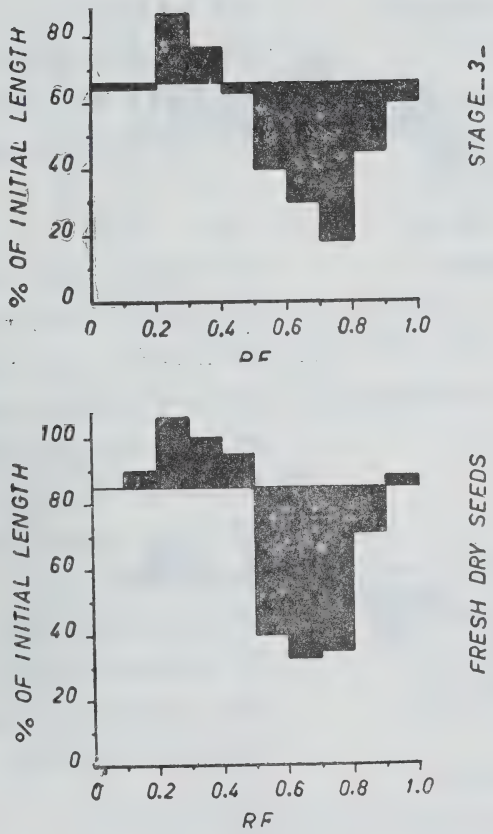

% OF INITIAL LENGTH
80
60
40
20
0
0
0.2
0.4
0.6
0.8
1.0
STAGE_3_
% OF INITIAL LENGTH
100
80
60
40
20
0
0
0.2
0.4
0.6
0.8
1.0
RF
FRESH DRY SEEDS

Fig. 2

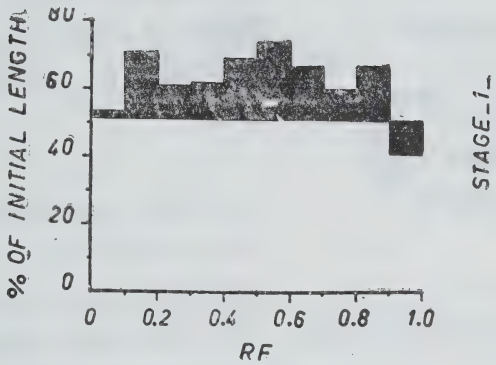
Chemical Tests for Water Extracts of Prunus Seeds at Different Stages of Development .

Stage (1). (Fig. 3 Upper)

1) **Ehrlish's reagent.**	RF 0.3-0.6 faint red.
	RF 0.85-0.95 violet colour.
2) **Ferric/Perchloric.**	RF 0.3-0.6 faint yellow.
	RF 0.85-0.95 yellowish.
3) **Nitrous/Nitric.**	- ve.
4) **Ethanolic Fe cl_3.**	- ve.
5) **Iodine solution**	RF 0.0-0.13 colour reduced.
	RF 0.37-0.5 colour reduced.
	RF 0.8-0.9 colour reduced.
6) **Potassium permanganale.**	RF 0.0-0.13 colour reduced.
	RF 0.36-0.5 colour reduced.
	RF 0.8-0.9 colour reduced.
7) **Ninhyrin.**	RF 0.0-0.1 violet colour.

Stage (2). (Fig. 3 Lower)

1) **Ehrish's reagent.**	RF 0.33-0.58 faint red.
	RF 0.8-0.88 faint violet.
2) **Ferric/Perchloric:**	RF 0.32-0.58 faint vlolet.
	RF 0.8-0.88 yellowish.
3) **Nitrous/Nitric:**	- ve.
4) **Ethanolic Fe cl_3:**	- ve.
5) **Iodine solution:**	RF 0.0-0.1 colour reduced.
	RF 0. 4-0.5 colour reduced.
	RF 0. 8-0.9 colour reduced.
6) **Potassium permanganate:**	RF 0.0-0.1 colour reduced.
	RF 0.4-0.5 colour reduced.
	RF 0.8-0.9 colour reduced.
7) **Ninhvdrin:**	RF 0.0-0.15 violet colour.


% OF INITIAL LENGTH
80
60
40
20
0
0
0.2
0.4
0.6
0.8
1.0
RF
STAGE_1_

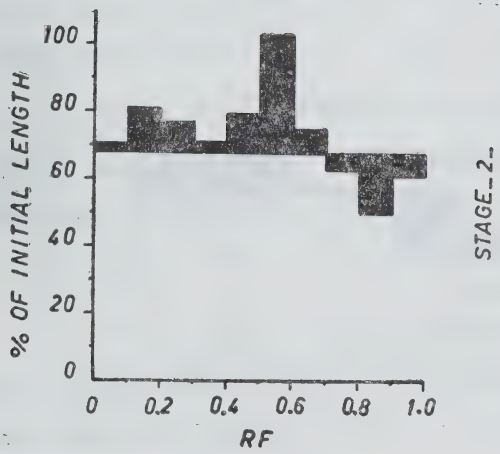

% OF INITIAL LENGTH
100
80
60
40
20
0
0
0.2
0.4
0.6
0.8
1.0
RF
STAGE_2_

Fig. 3

Stage (3). (Fig. 4. Upper)

1)	**Ehrlish's reagent.**	RF. 0.33-0.58 faint red.
		RF. 0.85-0.95 violet.
2)	**Ferric/Perchloric.**	RF. 0.3-0.6 faint yellow.
		RF. 0.83-0.96 yellowish.
3)	**Nitrous/Nitric.**	— ve.
4)	**Ethanolic Fe cl_3**	— ve.
5)	**Iodine solution.**	RF 0.0-0.1 colour reduced.
		RF 0.39-0.5 colour reduced.
		RF 0.8-0.9 colour reduced.
6)	**Potassium permanganate.**	RF 0.0-0.1 colour reduced
		RF 0.39-0.5 colour reduced.
		RF 0.8-0.9 colour reduced.
7)	**Ninhydrin.**	RF 0.0-0.1 violet colour.

Stage (4). (Dry dormant seeds) (Fig. 4. Lower)

1)	**Ehrlish's reagent.**	RF 0.3-0.4 faint red colour
		RF 0.85-0.95 violet colour
2)	**Ferric/Perchloric.**	— ve.
3)	**Nitrous/Nitric.**	— ve.
4)	**Ethanolic Fe cl_3**	— ve.
5)	**Iodine solution.**	RF 0.22-0,5 colour reduced.
		RF 0.71-0.87 colour reduced.
		RF 0.92-1.0 colour reduced.
6)	**Potassium permanganate.**	RF 0.22-0.5 colour reduced.
		RF 0.71-0.87 colour reduced.
		RF 0.92-1.0 colour reduced.
7)	**Ninhydrin.**	— ve.

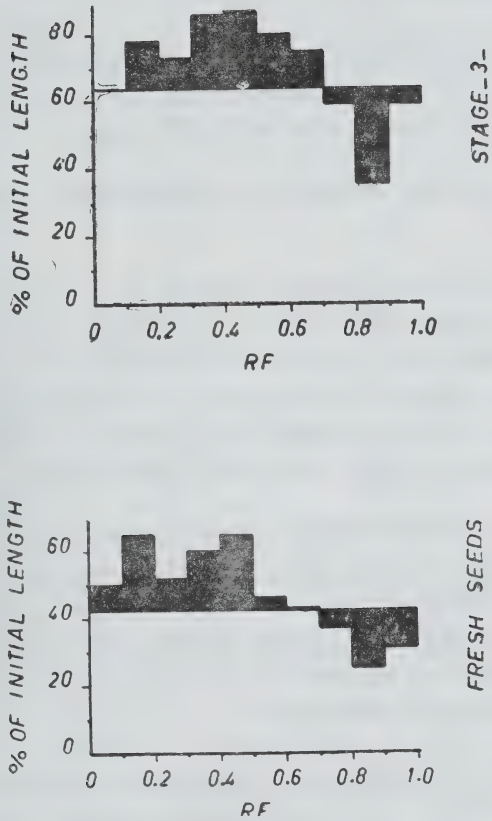

% OF INITIAL LENGTH
80
60
40
20
0
0
0.2
0.4
0.6
0.8
1.0
RF
STAGE_3_
% OF INITIAL LENGTH
60
40
20
0
0
0.2
0.4
0.6
0.8
1.0
RF
FRESH SEEDS

Fig: 4

Twenty freshly harvested intact **Prunus** seeds and twenty old ones (one year old) were planted in petri-dishes on moistened filter papers at room temperature (about 28°C). The number of germinated seeds was counted after 5 days.

It has been found that the intact freshly havested seeds do not show any sign of germination even after 20 days, while the old seeds show 100°/₀ germination after only five days.

2) Effect of Dry Storage on Germination of Dormant Prunus Seeds :-

A period of dry storage is found to be sufficient to break the dormancy of many seeds. Crocker and Barton (22) listed more than 50 species of plants, the dormant seeds of which become capable of germination after a period of dry storage. The following experiment was carried out to study the effect of dry storage at room temperature on the germination of freshly harvested **Prunus** seeds.

Freshly havested **Prunus** seeds that were harvested on **15 th** of May, 1960 were stored under dry conditions at room temperature (25°C-28°C). Twenty intact seeds were planted on moistened filter in papers petri-dishes at 15-day intervals over a period of 5 months and the number of germinated seeds was counted after five days. The results are shown in Table (2).

It has been found that dry storage at room temperature for about five months is quite enough to after-ripen the freshly harvested dormant seeds of **Prunus armeniaca var. Baladi**.

Table (2)

Effect of Dry storage on Germination of Do mant **Prunus** seeds

Date of planting	No. of germinated seeds
15/5/1960	0
30/5/1960	0
15/6/1960	0
30/6/1960	0
15/7/1960	0
30/7/1960	0
15/8/1960	1
30/8/1960	3
15/9/1960	2
30/9/1960	5
15/10/1960	20
30/10/1960	20

3) Effect of Chilling on Germination of Dormant Prunus Seeds:

The cold treatment under moist conditions had been reported by many investigators to be effective in breaking dormancy of many seeds (8). This effect was studied, in the following experiment, in relation to the dormancy of freshly-harvested **Prunus** seeds.

Soaked freshly harvested **Prunus** seeds were stored in a refrigirator at about 5°C for 21 days. At intervals of three days, samples of 10 seeds were planted in petri-dishes on moistened filter papers at room temperature. The number of germinated seeds in each case is shown in table (3).

Cold treatment of moistened freshly harvested **Prunus** seeds for nine days has been found to have a significant effect in breaking the dormancy of the seeds.

Table (3)

Effect of Chilling on Germination of Dormant Prunus seeds.

Time of chilling in days	No. of germinated seeds
3	
6	
9	8
12	10
15	10
18	10
21	10

(4) Effect of Some Rest-Breaking Chemicals on Germination of Dormant Prunus Seeds : -

Some chemicals are effective in breaking the dormancy of seeds, buds and tubers. Thiourea has been reported to break dormancy of many seeds (43, 44, 37, 47, 21), buds and tubers (9, 10, 11, 13, 25, 15). Ethylene cholrohydrin has been also found to be effective in breaking the dormancy of buds, tubers and some seeds (12, 16, 22, 36, 14, 23, 25, 21). The effect of these two chemicals was tested on germination of dormant **Prunus** seeds.

Twenly intact freshly harvested **Prunus** seeds were planted in petri-dishes on filter papers moistened with 1°/o and 0.5°/o aqueous solutions of thiourea and and ethylene chlorohydrin. All dishes were then kept at laboratory temperature (28°C). The germination results are recorded in Table (4).

Thiourea and ethylene chlorohydrin have been shown to have no significant effect in breaking the dormancy of **Prunus** seeds differing in this respect from many other seeds which are mentioned above.

It was also found that aqueous solutions of yeast extract and indole- acetic acid have no effect with regard to the germination of dormant **Prunus** seeds.

Table (4)

Effect of Thiourea and Ethylene Chlorohydrin on the Germination of Dormant Prunus Seeds.

Concentration	No. of Germinated seeds	
	Thiourea	Ethylene Chlorohydrin
1 %	2	0
0.5 %	0	0
Control	0	0

5) Effect of Excising Embryos of Dormant Prunus Seeds on Germination

The failure of some freshly harvested seeds to germinate may be due to the seed coats or other incasing structures. If these coats are removed, such seeds will germinate. The following experiment was carried out to show the possible effect of seed coat with regard to the dormancy of **Prunus** seed.

Twenty intact dormant **Prunus** seeds were soaked in water for an hour at room temperature (28°C) to soften the seed coat. The embryos were then excised and planted in a petri-dish on moistened filter papers. Twenty other intact dormant seeds were soaked in water for an hour at room temperature and then planted directly on moistened filter papers as a control. The seeds were kept at laboratory temperature (28°C) and the results of germination were recorded after five days.

The intact **Prunus** seeds failed to germinate, while the excised embryos showed 100% germination.

6) Effect of Oxygen on Germination of Dormant Prunus Seeds.

Twenty intact dormant **Prunus** seeds were planted in a petri-dish on moistened filter papers in an atmosphere of pure oxygen at room

temeprature (28°C), A control experiment was carried out in the ordinary air at the same temperature. The number of germinated seeds was recorded in each case.

It was found that no germination occurred in the ordinary air nor in the atmosphere of pure oxygen even after one month.

Discussion.—

A period of dry storage may be quite enough for breaking the dormancy of many seeds. Such period varies with species and varieties from few days to several months.

It was found that **Prunus armeniaca** seeds var. Baladi are dormant immediately after harvest. They emerge from dormancy after five months dry storage at laboratory temperature. The possible changes envolved during after-ripening in dry storage will be discussed later.

Cold treatment of soaked dormant seeds is known to be very effective in breaking the dormancy of many kinds of seeds. Roe (39) stated that dormant seeds of **Prunus armeniaca** can germinate after five months chilling at 5°C. In the present investigation it was found that only nine days chilling at the same temperature produced 80% germination and 12 days produced 100% germination. Such a great difference in the time of chilling required for complete breaking of **Prunus armeniaca** seed dormancy may be due to certain physiological differences between the two varieties.

Thiourea, ethylene chlorohydrin, yeast extract, indoleacetic acid solutions and high oxygen tension were found to have no effect in breaking dormancy of **Prunus** seeds, although they were found to be effective in breaking dormancy of many kinds of seeds, buds and tubers.

The embryos of many kinds of dormant seeds germinate readily and grow vigorously when the seed - coats are broken (7, 19, 8).

Excising the embryos of dormant **Prunus armeniaca** seeds was found to be very effective in breaking their dormancy.

The possible mechanisms of dry storage and chilling in relation to the dormancy of **Prunus** seeds will be discussed below.

The Possible Role of Growth-Inhibitors in the Dormancy of Prunus Seeds

It has been found that dry storage and cold treatment are very effective in breaking the dormancy of the freshly harvested **Prunus** seeds. It has been also shown that certain natural growth-inhibitors appear gradually during the seed development. These observations raise the question as to whether such growth-inhibiting substances may play any role in dormancy. The following experiments were carried out to investigate any such possible role.

1) Effect of Dry Storage on the Growth Substance Content of Dormant Prunus Seeds :-

Many investigators suggested that the disappearance of the growth-inhibitory substances may be concerned in the breakdown of dormancy of many dormant seeds in dry storage (2, 19, 35).

The following experiment was carried out to study the effect of dry storage on the inhibitor and hormone contents of **Prunus** seeds.

Method :-

A quantity of freshly harvested dormant **Prunus** seeds was extracted succesively with 96°/₀ redistilled ethyl alcohol and distilled water as the normal procedure.

Another sample of old **Prunus** seeds (nondormant) was also extracted in the same manner.

An extract equivalent to that obtaided from 2 gm. dry weight of seeds in each fraction was loaded and run on a chromatogram using 80°/₀ isopropyl alcohol as a running solvent.

Effect of Dry Storage on Hormone and Inhibitor Contents of Prunus Seeds : A) Alcohol Extracts :

Fresh Dormant Seeds : (Fig. 5, Upper).

1) **Ehrlish's reagent** : RF 0.4-0.8 red changed into violet colour.
2) **Ferric/Perchloric** : RF 0.4-0.8 pale red
3) **Nitrous/Nitric** : RF 0.4-0.8 yellowish colour.
4) **Ethanolic Fe cl_3** : — ve.
5) **Iodine solution** RF 0.4 — 0.8 colour reduced.
6) **Potassium permanganate** : RF 0.4 – 0.8 colour reduced.
7) **Ninhydrin** : RF 0.0 – 0.25 violet colour.
   RF 0.5 - 0.6 violet colour

Old Nondormant Seeds : (Fig. 5, Lower)

1) **Ehrlish's reagent** : RF 0.38 – 0.79 red changed into violet colour.
2) **Ferric/Perchloric** : RF 0.4—0.8 pale red.
3) **Nitrous/Nitric** : RF 0.4—0.8 yellowish colour.
4) **Ethanolic Fe cl_3** : — ve.
5) **Iodine solution** : RF 0.35 – 0.82 colour reduced.
6) **Potassium permanganate** : RF 0.35—0.82 colour reduced.
7) **Ninhydrin** : RF 0.0—0.25 violet colour.
   RF 0.5—0.6 violet colour.

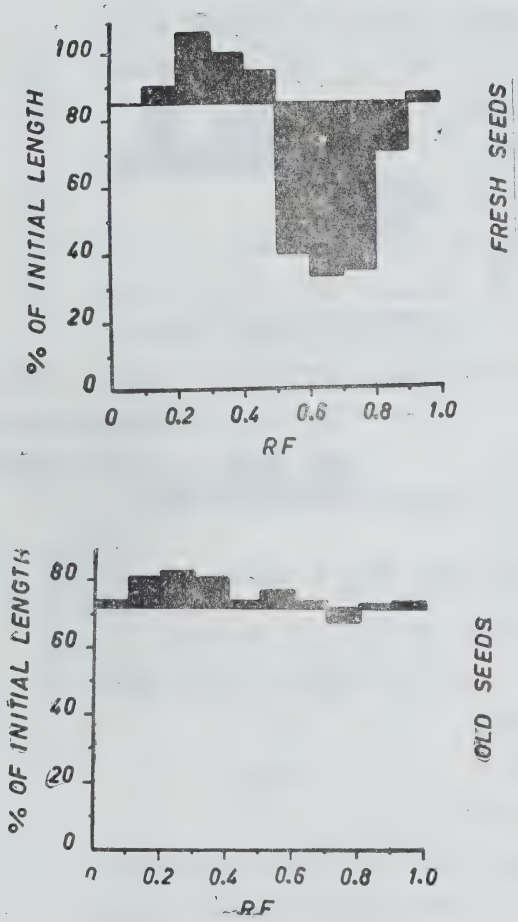

% OF INITIAL LENGTH
100
80
60
40
20
0
0
0.2
0.4
0.6
0.8
1.0
RF
FRESH SEEDS
% OF INITIAL LENGTH
80
60
40
20
0
0
0.2
0.4
0.6
0.8
1.0
RF
OLD SEEDS

Fig. 5

Effect of Dry Storage on Hormone and Inhibitor Contents of Prunus Seeds : B) Water Extract

Fresh Dormant Seeds : (Fig. 6_1 Upper)

1) **Ehrlish's reagent.** RF 0.3 0.4 faint red colour.
   RF 0.85-0.95 violet colour.
2) **Ferric/Perchloric.** — ve.
3) **Nitrous/Nitric.** — ve.
4) **Ethanolic Ee cl_3** — ve.
5) **Iodine solution,** RF 0.22–0.5 colour reduced.
   RF 0.71–0.87 colour reduced.
   RF 0,92–1.0 colour reduced.
6) **Potassium permanganate.** RF 0.22 0.5 colour reduced.
   RF 0.71–87 colour reduced.
   RF 0.92 1.0 colour reduced.
7) **Ninhydrin.** — ve.

Old Nondormant Seeds: (Fig. 6. lower).

1) **Ehrlish's reagent.** RF 0.3—0.4 faint red.
   RF 0.85—0.95 violet colour.
2) **Ferric/Perchloric.** — ve.
3) **Nitrous/Nitric.** — ve.
4) **Ethanolic Fe Cl_3** — ve.
5) **Iodine solution.** RF 0.25—0.52 colour reduced.
   RF 0.75–0.88 colour reduced.
   RF 0.93—1.0 colour reduced.
6) **Potassium permanganate.** RF 0.25–0.52 colour reduced.
   RF 0.75–0.88 colour reduced.
   RF 0.93—1.0 colour reduced.
7) **Ninhydrin.** — ve.

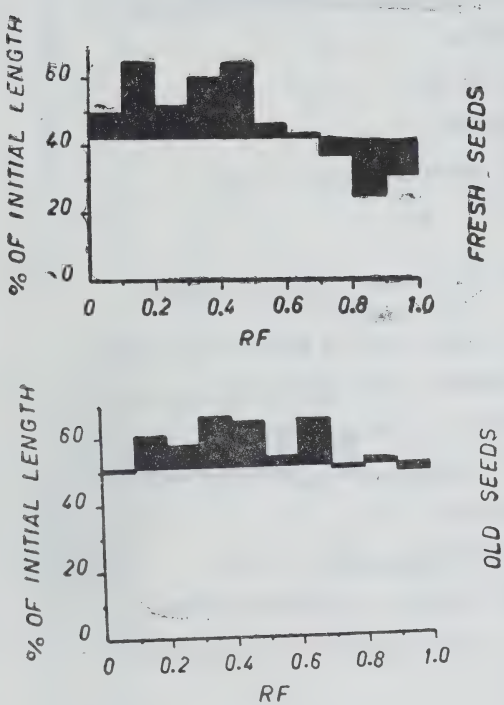

% OF INITIAL LENGTH
60
40
20
0
0
0.2
0.4
0.6
0.8
1.0
RF
FRESH SEEDS
% OF INITIAL LENGTH
60
40
20
0
0
0.2
0.4
0.6
0.8
1.0
RF
OLD SEEDS

Fig. 6

Chemical Tests for Alcohol Extracts of Prunus Seeds at Different Periods of Chilling :

Chilling for 3 days: (Fig. 7, upper)

1) **Ehrlish's reagent** . RF 0.1 -0.8 faint red.
2) **Ferric/Perchloric** : — ve.
3) **Nitrous/Nitric** : — ve.
4) **Ethanolic Fe cl_3** : — ve.
5) **Iodine solution** : — ve.
6) **Potassium permanganate** : — ve.
7) **Ninhydrin** : — ve

Chilling for 6 days ; (Fig. 7. Lower)

1) **Ehrlish's reagent** : RF 0.4–0.78 red colour.
2) **Ferric/Perchloric** : RF 0.4–0.78 faint red.
3) **Nitrous/Nitric** : — ve.
4) **Ethanolic Fe cl_3** : — ve.
5) **Iodine solution** ; — ve.
6) **Potassium permanganate** : — ve.
7) **Ninhydrin** : RF 0.1—0.3 violet colour.
   RF 0.53—0.69 violet colour.

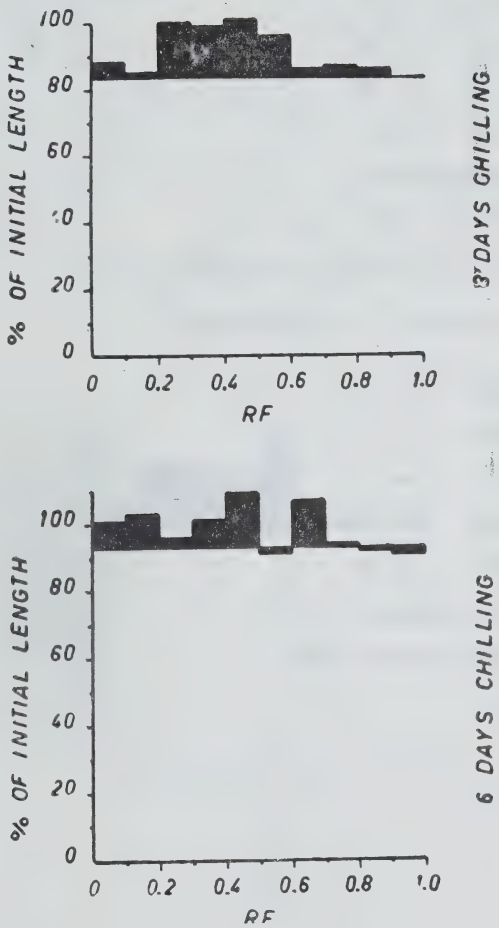

% OF INITIAL LENGTH
100
80
60
40
20
0
0
0.2
0.4
0.6
0.8
1.0
RF
3 DAYS CHILLING
% OF INITIAL LENGTH
100
80
60
40
20
0
0
0.2
0.4
0.6
0.8
1.0
RF
6 DAYS CHILLING

Fig. 7

Chilling for 9 days : (Fig. 8 Upper)

1) **Ehrlish's reagent :** RF 0.48—0.73 red colour.
2) **Ferric/Perchloric:** — ve.
3) **Nitrous/Nitric:** — ve.
4) **Ethanolic Fe cl_3 :** — ve
5) **Iodine solution :** — ve.
6) **Potassium permanganate :** — ve.
7) **Ninhydrin :** RF 0.1—0.3 violet colour.
   RF 0.55—0.65 violet colour.

Chilling for 12 days : (Fig. 8 Lower)

1) **Ehrlish's reagent :** — ve.
2) **Ferric/Perchloric :** — ve.
3) **Nitrous/Nitric :** — ve.
4) **Ethanolic Fe cl_3 :** — ve.
5) **Iodine solution :** — ve.
6) **Potassium Permanganate ;** — ve.
7) **Ninhydrin :** RF 0.0—0.15 violet.

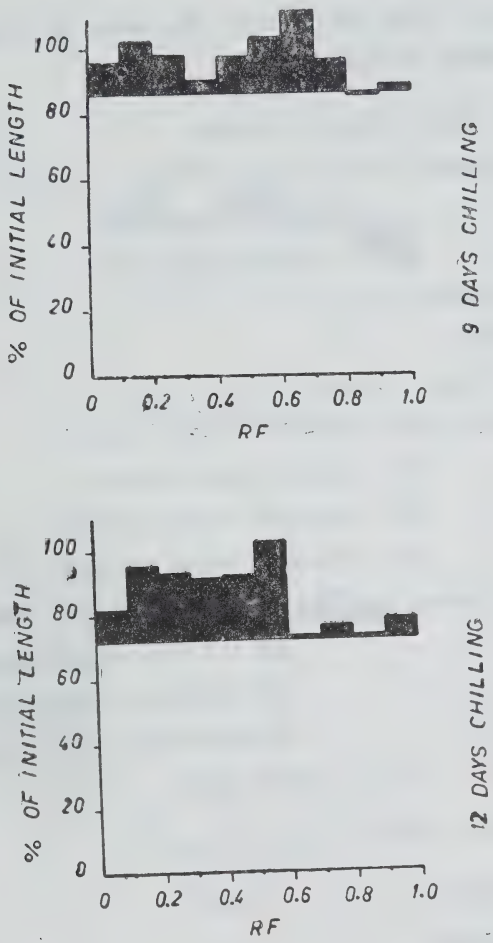

% OF INITIAL LENGTH
100
80
60
40
20
0
0
0.2
0.4
0.6
0.8
1.0
RF
9 DAYS CHILLING
% OF INITIAL LENGTH
100
80
60
40
20
0
0
0.2
0.4
0.6
0.8
1.0
RF
12 DAYS CHILLING

Fig. 8

Chemical Tests for Water Extracts of Prunus Seeds at Different Chilling Periods :

Chilling for 3 days : (Fig. 9, Upper)

1) **Ehrlish's reagent :** RF 0.0—0.2 violet.
   RF 0.5—0.7 faint red.
   RF 0.5—0.7 faint red.
2) **Eerric/perchloric :** — ve.
3) **Nitrous/Nitric :** — ve.
4) **Ethanolic Fe cl_3 :** — ve.
5) **Iodine solution :** RF 0.16—0.2 colour reduced.
   RF 0.4—0.5 colour reduced.
   RF 0.62—0.73 colour reduced.
   RF 0.83—0.92 colour reduced.
6) **Potassium permanganate :** RF 0.16—0.2 colour reduced.
   RF 0.4—0.5 colour reduced.
   RF 0.62—0.73 colour reduced.
   RF 0.83—0.92 colour reduced.
7) **Ninhydrin:** RF 0.4—0.5 Yellow colour.

Chillin5 for 6 days : (Fig, 9 Lower)

1) **Ehrlish's reagent :** — ve.
2) **Ferric/Perchloric:** — ve.
3) **Nitrous/Nitric:** — ve.
4) **Ethanolic Fe cl_3:** — ve.
5) **Iodine solution:** — ve.
6) **Potassium permanganate:** — ve.
7) **Ninhydrin :** RF 0.0—0.05 violet.

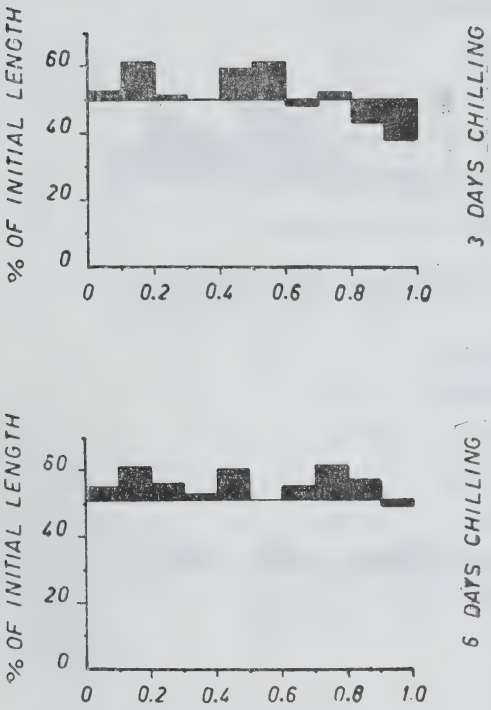

% OF INITIAL LENGTH
60
40
20
0
0
0.2
0.4
0.6
0.8
1.0
3 DAYS CHILLING
% OF INITIAL LENGTH
60
40
20
0
0
0.2
0.4
0.6
0.8
1.0
6 DAYS CHILLING

Fig. 9

Chilling for 9 days. (Fig. 10 Upper)

1) **Ehrlish's reagent:** RF 0.0—0 3 'blue colour.
2) **Ferric/Perchloric** : — ve.
3) **Nitrous/Nitric** : — ve.
4) **Ethanol'c Fe cl_3:** — ve.
5) **Iodine solution** : — ve.
6) **Potassium permanganate** : — ve.
7) **Ninhydrin** : RF 0.0—0.3 violet.

Chilling for 12 days. (Fig. 10 Lower)

1) **Ehrlish's reagent** : — ve.
2) **Ferric/Perchloric:** — ve.
3) **Nitrous/Nitric** : — ve.
4) **Ethanolic? Fe cl_3:** — ve.
5) **Iodine solution** : — ve.
6) **Potassium permanganate** : — ve.
7) **Ninhydrin** : RF 0 0 0.03 violet.

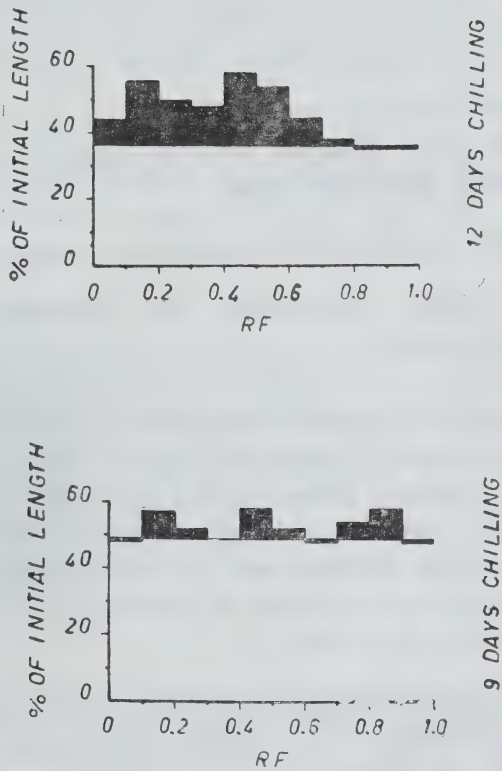

% OF INITIAL LENGTH
60
40
20
0
0
0.2
0.4
0.6
0.8
1.0
RF
12 DAYS CHILLING
% OF INITIAL LENGTH
60
40
20
0
0
0.2
0.4
0.6
0.8
1.0
RF
9 DAYS CHILLING

Fig. 10

The different chromatograms were then simultaneously assayed by the straight growth test using **Hordeum** coleoptile sections. The results are shown in Fig. (5) for alcohol fractions and in Fig. (6) for aqueous ones.

Results :-

The natural inhibitory substances present in freshly harvested dormant **Prunus** seeds, disappear from the alcohol and the aqueous fractions of the old nondormant ones.

The growth promoters show no significant changes.

2) Effect of Chilling on hormone and Inhibitor Contents of Dormant Prunus Seeds.-

It bas been shown by many investigators that the growth inhibiting substances, present in dormant organs decrease or completely disappear when the rest is broken by cold treatment (26, 27, 28, 29, 30, 31, 42, 4, 33). Some workers are of the opinion that the disappearance of the growth inhibitors and the formation of growth promoters may be concerned in the break of dormancy of seeds and buds by cold treatment (2, 35, 4. 41).

During the present investigation it has been observed that cold treatment is very effective in breaking the dormancy of freshly harvested **Prunus** seeds. The following experiment was carried out to determine whether cold treatment is associated with any significant differences in hormone and inhibitor contents of seeds during their chilling.

Method :

Soaked dormant **Prunus** seeds were stratified in moistened sand at about 5°C. At intervals of three days, samples of seeds were taken, frozen hard, ground to a powder and then extracted by the usual procedure. Extracts equivalent to that obtained from 2 gm. dry weight of seeds were simultaneously loaded, developed on different chromatograms and then assayed by the straight growth method using **Hordeum** coleoptile sections.

The results of alcohol extracts are shown in Fig. (7) and (8), and those of aqueous extracts are presens in Fig. (9) and (10).

Results .—

The cold treatment of dormant **Prunus** seeds under moist conditions has a significant effect on their inhibitor content. It is clearly shown that after three days chilling, the inhibitors of dormant seeds completely disappear. The alcohol soluble promoters show some increase after 9 & 12 days chilling. The activity of the aqueous promoters also show a little increase after 12 days chilling.

Discussion

It has been found that there is a marked decrease in hormone-content of apricot seeds towards maturity, The promoting substances show their maximum activities during active stages of seed development and then they decrease as the seeds become fully mature. These results suggest that such promoters may play a epcifici role in the development of **Prunus** seeds.

The freshly harvested fully mature **Prunus** seeds were found to be dormant. Such dormancy is correlated with the presence of some growth inhibiting substances. The activities of these inhibitors increase gradually and reach their maximum as the seeds become fully mature. This result raises the question as to whether the occurrence of the inhibitors in **Prunus** seeds may have any role in their dormancy.

If dormancy of **Prunus armeniaca** seeds is due to the presence of these inhibitory substances, there ought to be some correlations between the presence or absence of inhibitors and the state of seed dormancy.

In the early stages of **Prunus** seed development, the growth inhibiting substances are at a low concentrations. As the seeds reach their full size, the inhibitors go on increasing, reaching their maximum level when seeds become fully mature.

The level of the inhibitor content of mature **Prunus** seeds decreases during dry storage and completely disappear in the after-ripened seeds.

Cold treatment of dormant **Prunus armeniaca** seeds has been found to be very effective in breaking the dormancy. The emergence of **Prunus** seeds from dormancy by chilling is correlated with the disappearance of the seed inhibitors before any sign of germination. Thus the main periods of accumulation and disappearance of the seed inhibitors agree closely with the expectation, that these growth inhibitory substances play a role in controlling dormancy. The disappearance of the growth inhibiting substances during after-ripening agrees with the results obtained by Hemberg (27, 28, 29, 30, 31), Spiegel (41), Blommaert (4) and Hendeshott and Bailey (33) who observed that, during the early stages of dormancy, buds of certain species are very rich in growth inhibitors which decrease gradually and disappear as the buds emerge from dormancy.

The early stages of germination of **Prunus** seeds are accompanied by a significant increase in the hormone content. Such increase may cause an initiation of the mitotic division of the meristematic cells of the embryonic root resulting in its emergence through the testa.

SUMMARY

1. The changes of growth regulating substances, during different stages of development and germination of **Prunus armeniaca** seeds were studied.

2. The growth substances were extracted, separated by paper chromatography and then bioassayed by the straight growth of **Hordeum** coleoptile.

3. Two growth-inhibiting substances were extracted from **Prunus** seeds. They showed a gradual increase in their activities towards seed maturity.

4. Freshly harvested **Prunus** seed were found to be dormant.

5. Dry storage for five months was found to be sufficient to prepare the dormant **Prunus** seeds for germination.

6. Cold treatment of dormant **Prunus** seeds for 12 days at 5°C was found to be very effective in breaking the dormancy.

7. Excising the embryos of dormant **Prunus** seeds was shown to be also very effective in breaking the dormancy.

8. Thiourea, ethylene chlorohydrin, yeast extract, indoeactic acid and high oxygen tension were found to have no effect in breaking dormancy of **Prunus** seeds.

9. The growth-inhibitors present in dormant **Prunus** seeds disappeared during their after-ripening in dry storage and cold tretment

10. The possible role of the natural growth regulators in relation to the dormancy of apricot seeds was discussed.

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STUDIES ON NATURAL CROWTH INHIBITORS OF APRICOT SEEDS

By

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Faculty of Science, Ain Shams University, Cairo.

Effect of Gell - Free Extract on the Activity of Seed Inhibititors of Prunus armeniaca :

It has been shown* that the inhibiting substances of freshly harvested dormant **Prunus armeniaca** seeds disappear during the breakdown of seed dormancy by dry storage and cold stratification. This suggests that such inhibitors may undergo enzymatic breakdown during after ripening of dormant seeds. The following preliminary experiments were carried out to test such hypothesis.

Enzyme Preparation :

The method used was similar to that ef Andreae and Andreae (2).

Non-dormant **Prunus** seeds were planted in moistened sand in plastic boxes at laboratory temperature (28° C.). After ten days, the seedlings were harvested and frozen hard by placing them in deep freeze overnight. This frozen tissues were then macerated in a minimum amount of cold distilled water at 0°C in a mortar. The resulting brei was then passed through a muslin cloth and the cell-free extract was precipitated with ethyl alcohol. After centrifugation, the residue was waehed with 96°/₀ redistilled ethyl alcohol and then taken up in a minimum amount of cold distilled water.

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Effect of Cell-Free Extract on the Inhibitors of Prunus Seeds in vitro:

Andreae and Andreae (2) succeeded in oxidizing scopoletin, which is a natural occurring growth-inhibitor, by a cell-free extract prepared from the seedlings of peas. Foda (7) found that the cell-free extract prepared from **Xanthium** seedlings or from the leaves of older plants is capable of bringing about a breakdown of tho seed inhibitors **in vitro** The following experiment was carried out to investigate the effect of the cell-free extract of **Prunus** seedlings on the breakdown of the inhibiting substances of dormant seeds.

Method :

Alcohol extract equivalent to that from 2 gm. dry weight of dormant **Prunus** seeds was added in a test tube to a cell-free extract equivalent to that from 2 gm. dry weight of seedlings. Another equal portion of the alcohol seed extract was kept in a second test tube at the same time, without cell-free extract, as a control. The two tubes were incubated at 30°C overnight. The contents of the two tubes, after being concentrated at 30°C under full vacuum, were loaded and run on two chromatograms. The chromatograms were assayed by means of the straight growth method using **Hordeum** coloeptile sections.

The same procedure was repeated with the a aqueous extract of dormant **Prunus** seeds.

The results are shown in Fig. (1) for the alcohol extract and in Fig. (2) for the aqueous extract.

Results:

The activity of the inhibiting substances of both alcohol and aqueous extracts of **Prunus** seeds in the presence of the enzyme preparation was significantly decreased as being compared with the activity of the controls. This result is compatible with the view that the breakdown' of the seed inhibitors is enzymatically controlled.

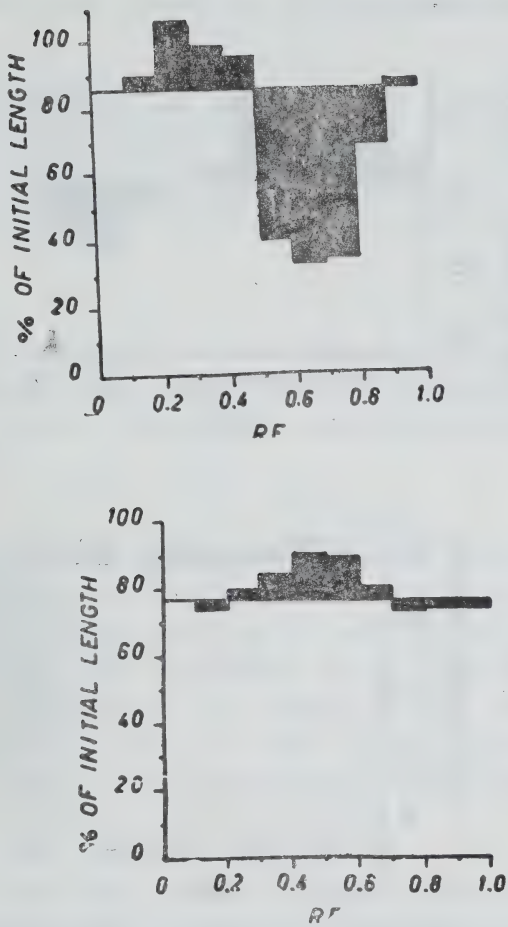

Fig 1 Effect of Cell-Free Extract on Alcohol Prunus *Seed Inhibitors*
Upper: No Cell-Free Extract.
Lower: + Cell-Free Extract.

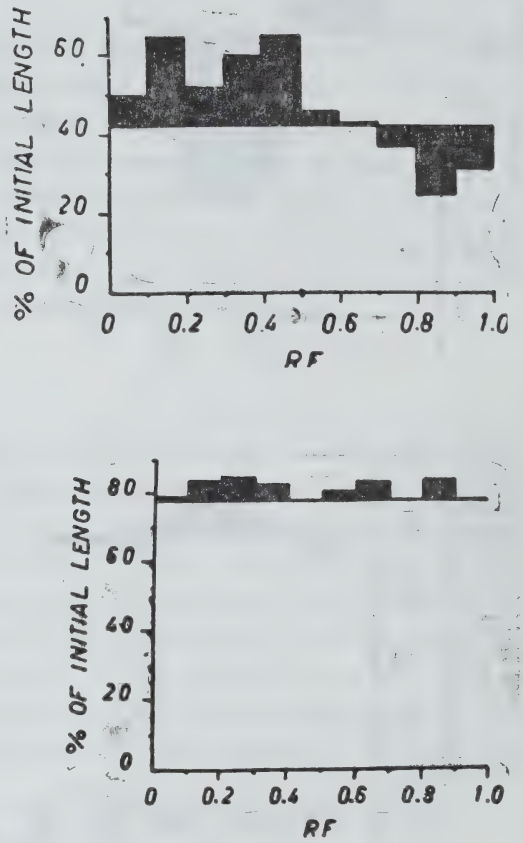

Fig. 2 Effect of Cell-Free Extract on Aqueous Prunus *Seed Inhibitor.*
Upper : No Cell-Free Extract.
Lower : + Cell-Free Extract.

Effect of Boiled Cell - Free Extract on the Inhibitors of Prunus Seeds in vitro :

The previous experiment was repeated using boiled cell-free extract to show whether or not the destruction of the inhibitors is due to a thermostable nonenzymatic substance. The results are expressed in Fig. (3) for alcohol fraction and in Fig. (4) for equeous fraction.

Results :

The boiled cell-free extract has no effect on the activity of **Prunus** seed inhibitors **in vitro** showing that the breakdown of the seed inhibitors is not due to a thermostable nonenzymatic substance.

Discussion :

The disappearance of the growth-inhibitors from **Prunus** seeds during the breaking down of their dormancy by dry storage agrees with the results of earlier investigators (3, 6, 15) Also the disappearance of such inhibitors during the break-down of the seed dormancy by cold treatment, is similar to the results obtained by other investigators (8, 9, 10, 11, 12, 13, 17, 4). Such results indicate that the growth inhibitors may play an essential role in controlling **Prunus** seed dormancy.

The fact that the fresh, but not the boiled, cell-free extract prepared from **Prunus** seedlings is capable of breaking down the growth inhibitors **in vitro**, indicates that an enzyme system is involved in the disappearance of the growth-inhibitors during after-ripening. The nature of such enzyme system, however, requires further investigation.

Possible Mechanism of Action of the Inhibiting Substauces of Pruuus armeniaca seeds.

A number of experiments was carried out to elucidate the effect of dilution and indoleacetic acid on the activity of **Prunus** seed inhibitors.

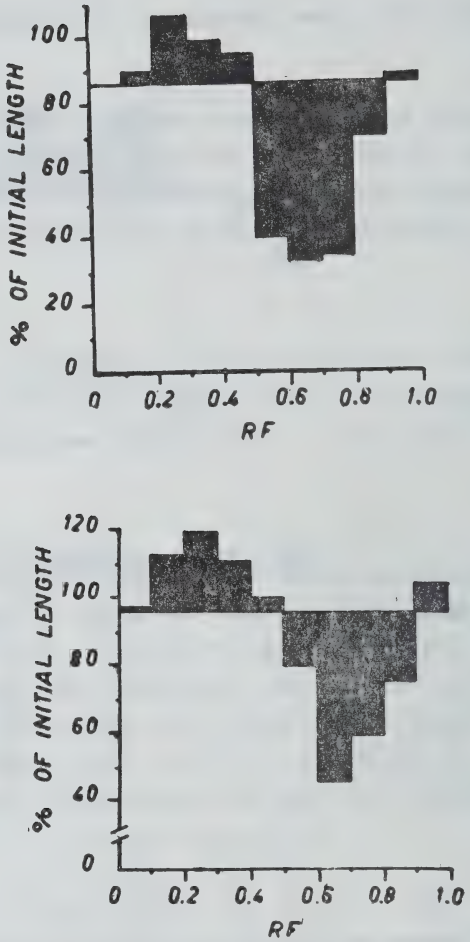

Fig. 3. Effect of Boiled Cell-Free Extract on Alcohol Soluble Prunus *Seed Inhibitor.*

Upper : No Cell Free Extract.
Lower : + Boiled Cell-Free Extract.

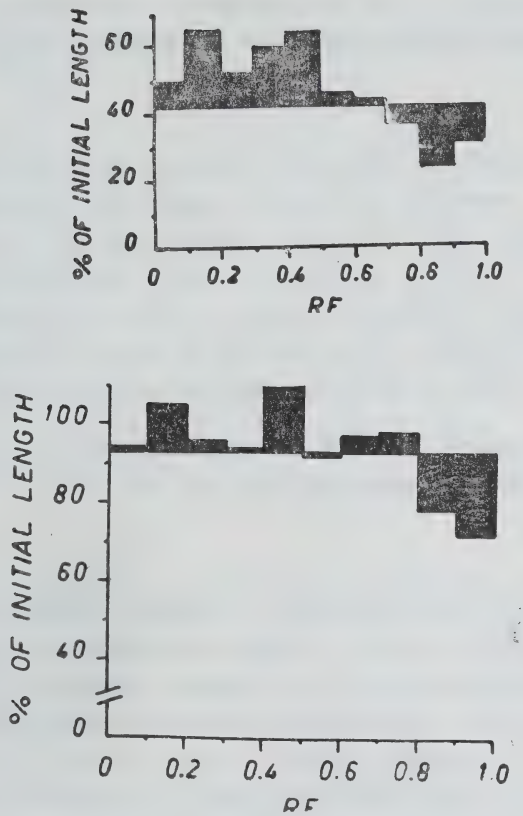

Fig. 4. Effect of Boiled Cell-Free Extract on Aqueous Prunus *Seed Inhibitor.*

Upper : No Cell-Free Extract.
Lower : + Boiled Cell-Frre extract.

a) **Effect of Dilution on the Activity of Seed Inhibitors :**

The activity of the seed inhibitors was studied over a range of dilutions using straight growth test of **Hordeum** coleoptile sections.

Method :

The alcohol as well as the aqueous inhibitors of **Prunus** seed were first separated by means of paper chromatography. Different dilutions were made from the alcohol and the aqueous inhibitors starting with extracts equivalent to that obtained from 2 gm. dry weight of seeds, for the former and 4 gm. dry weight of seeds, in 10 ml. water for the latter. The activity of these different dilutions was assayed by means of Hordeum coleoptile straight growth test.

The activity curve of the alcohol inhibitor is shown in Fig (5) and that of the aqueous one in Fig. (6).

Results :

Both fractions of inhibitors markedly inhibited the growth of **Hordeum** coleoptile sections at higher concentrations (2 gm. seeds for alcohol inhibitor and 4 gm. for aqueous inhibitor in 10 ml. water). At relatively lower concentrations, (0·02 gm. seeds for alcohol inhibitor and 0.4 gm. for aqueous inhibitor in 10 ml. water), on the other hand, they had a relatively promoting action on the growth of the coleoptile sections. The significance of such results will be discussed later.

b) **Interaction between the Inhibiting Substances of Prunus Seeds and Indolacetic Acid :**

The interaction between the inhibiting substances of **Prunus** seeds and indolacetic acid (IAA) was studied to find out whether it is possible for the growth promoting substance (IAA) to overcome the seed inhibitors.

Experiment I :

Interaction between **Prunus** seed inhibitors at constant concentrations and indoleacetic acid at different dilutions.

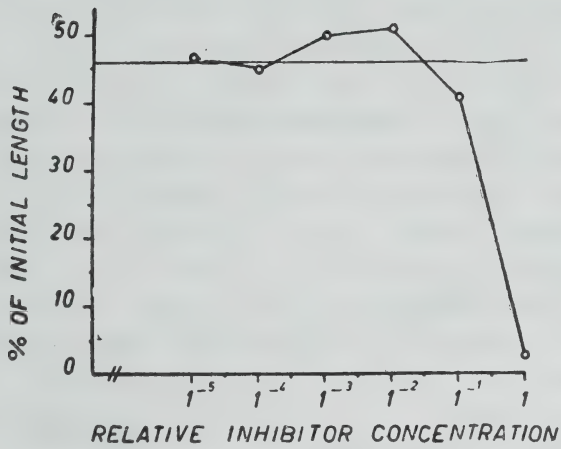

Fig. 5. Activity Curve For Alcohol Inhibitor.

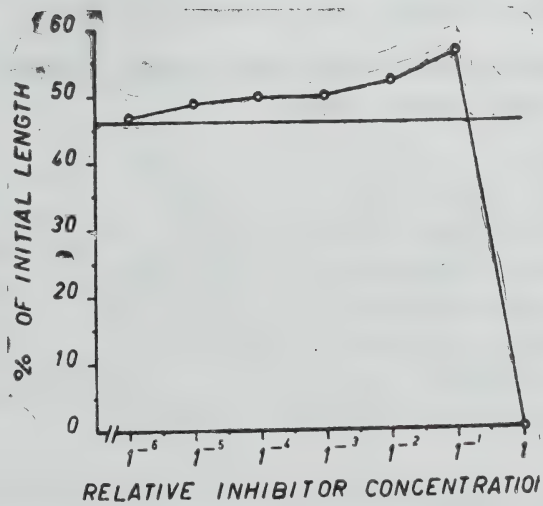

Fig. 6. Activity Curve For Aqueous Inhibitor.

Method :

The alcohol and aqueous inhibitors of Prunus seed were first separated by means of paper chromatography. Two series containing constant concentrations of each fraction were made. Each solution of one series of the alcohol fractions contained extract equivalent to that obtained from 1 gm. dry weight of seeds in 10 ml. distilled water, while extract equivalent to that obtained from 0.5 gm dry weight of seeds, was used in each solution of the series. In the aqueous extract, on the other hand, each solution of one series is equivalent to that obtained from 2 gm. dry weight of seeds in 1.0 ml. distilled water, while extract equivalent to that from 1.0 gm. dry weight of seeds in 10 ml. distilled water was used in each solution of the other series. Indoleacetic acid was added so that the final concentrations of the solutions of each series was 100 mg./1., 10 mg /1., 1 mg./1., 0.1 mg./1, 0.01 mg./1., 0.001 mg./1. and 0.0. respectively.

A control series of IAA at different concentrations was used, in the absence of seed inhibitors.

The activity of these different solutions was assayed by means of **Hordeum** coleoptile sections.

The results are shown in Fig. (7) for the alcohol inhibitor and in Fig. (8) for the aqueous inhibitor.

Results :

In case of the alcohol soluble inhibitor, it has been found that extract equivalent to that from 1 gm. dry weight of seeds in 10 ml. distilled water antagonizes the stimulatory effect of IAA, while at relatively lower concentrations (extract of 0.5 gm. dry weight of seeds in 10 ml. distilled water) the inhibitor shows slightly synergistic action with the auxin at its optimum concentration.

In case of apueous inhibitor, on the other hand, it has been found that the inhibitor shows a synergistic action with IAA at concentrations of 0.001 mg./1., 0.01 mg./1, 0.1 mg./1. and 1.0 mg./1.

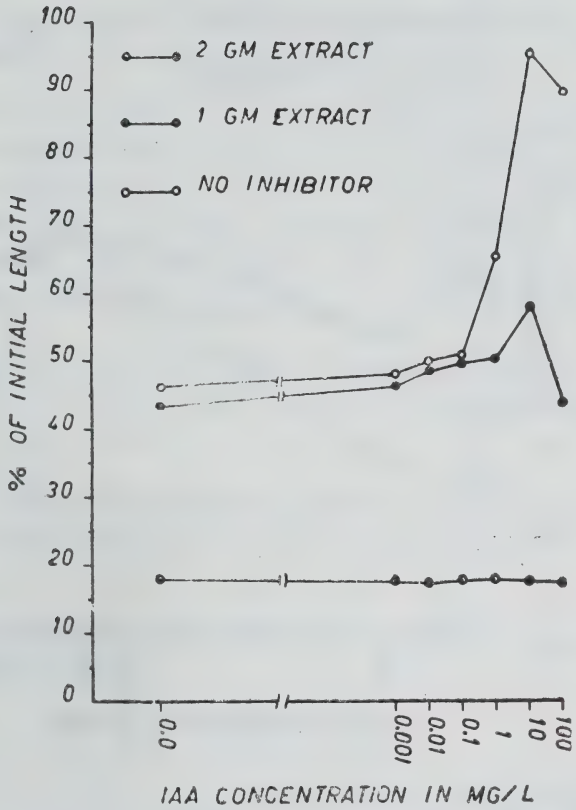

Fig. 7. Interaction Between IAA At Different Dilutions And Alcohol Prunus *Seed Inhibitor At Constant Concentration.*

White Circles : No Inhibitor.
Black Gircles : Inhibitor ≡ 0.5 *gm. Seeds*
Dotted Circles : Inhibttor ≡ 1 *gm. Seeds*

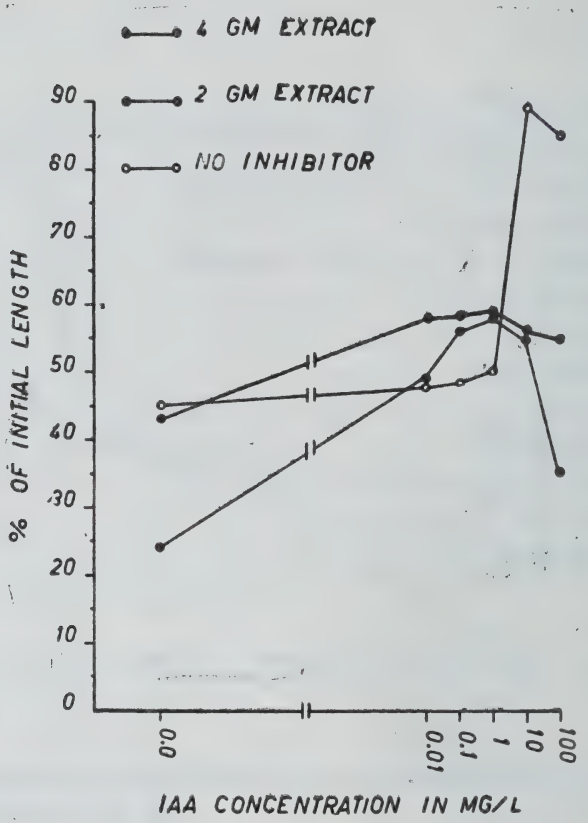

Fig. 8. *Interaction Between IAA At Different Dilutions And Aqueous* Prunus *Seed Inhibitor At Constant Concentrations.*

White Circles : No Inhibitor.
Black Circles : Inhibitor ≡ 4 gm. Seeds.
Dotted Circles : Inhibitor ≡ 2 gm. Seeds.

Experiment 2 :

Interaction between **Prunus** seed inhibitors at different dilutions and indoleacetic acid at a contant concentration.

Method : The seed inhibitors were first separated by paper chromatography. Two sets of different dilutions were then made for each of the alcohol and aqueous inhibitors, starting with extract equivalent to that obtained from 2 gm. dry weight of **Prunus** seeds in 10 ml. distilled water in case of the alcohol fraction and to that from 4 gm. dry weight of seeds, in 10 ml. water, in case of the aqueous inhibitors.

One set of each fraction was left without indoleacetic acid, while to the second set IAA was added so that the final concentration of each dilution was 10.0 mg./l.

The activitiy of the different dilutions was assayed by **Hordeum** coleoptile sections. Controls of IAA (10 mg./l.) aud distilled water were also assayed.

The results are shown in Fig. (9) for alcohol fraction and in Fig. (10) for aqueous one.

Results :

The seed inhibitors at relatively higher concentrations (2 mg. seeds for alcohol inhibitor and 4 gm. for aqueous inhiditor in 10 ml. water) antagonize the promoting effect of IAA, while at lower concentrations (0.02 gm. seeds for alcohol inhibitor and 0.04 gm. seeds for aqueous inhibitor in 10 ml. water), they show a slightly synergistic action with the auxin.

Discussion :

The study of the activity curves of the inhibitors of **Prunus** seed indicates that they have a strong inhibiting effect on the growth of the coleoptile sections at relatively high concentrations. At low concentrations, on the other hand, the seed inhibitors slightly stimulate the growth of the coleoptile sections. A number of investigators have recorded similar stimulatory effects at low concentrations of some growth inhibiting

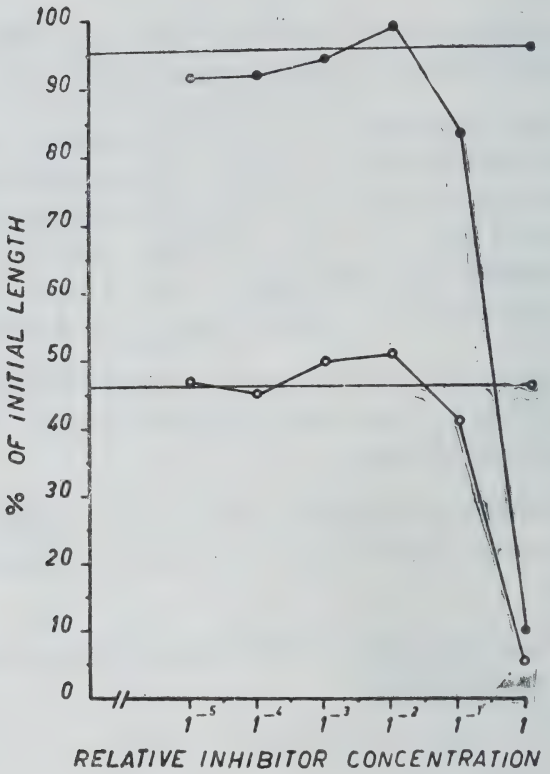

Fig. 9. *Interaction Between Alcohol* Prunus *Seed Inhibitor At Different Dilutions and IAA At A Constant Concentration.*

Black Circles : + *IAA.*
White Circles : *No IAA.*

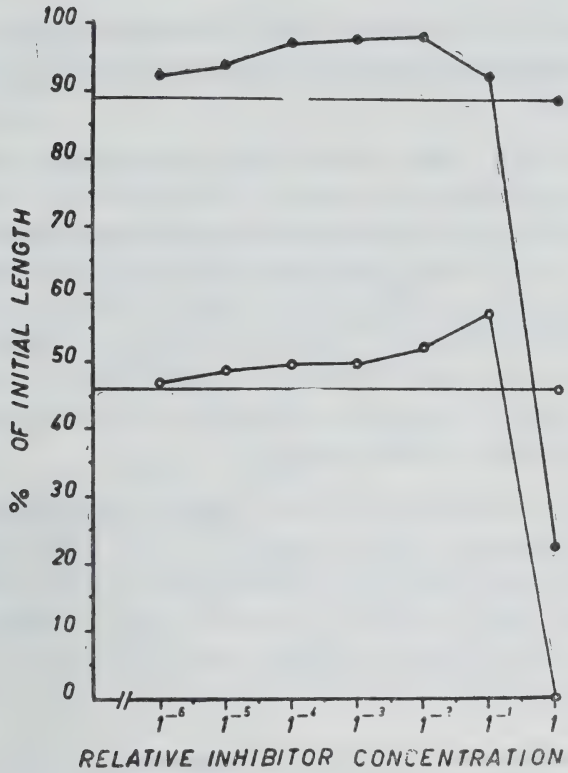

Fig. 10. *Interaction Between Aqueous* Prunus *Seed Inhibitor At Differeu Dilutions And IAA At A Constant Concentration.*

Black Circles : + *IAA.*
White Circles : *No IAA.*

substances, e.g. iodoacetate (18), coumarin and protoanemonin (19), cholidonic acid (14) and 2,3,5-tri-iodobenzoic acid (1).

Aberg is of the opinion that the stimulatory effect may be due to a synergistic action of the inhibitor with residual amounts of the native auxin.

At relatively high concentrations, the inhibitors of **Prunus** seeds antagonize the peromoting action of indoleacetic acid. In other words, their inhibitory action, at relatively high concentrations, cannot be overcome by the stimulatory effect of auxins. This may suggest the possible role of seed inhibitors with regard to dormancy of Prunus seeds. The high concentrations of the seed inhibitors completely antagonize the action of the growth hormones naturally present within the seed, and this could be considered, at least, one of the mechanisms by which the inhibitors may control dormancy.

As the concentration of seed inhibitors decreases the inhibitory action is changed to a slight synergistic effect with indoleacetic acid. Similar effects have been also recorded (9, 11, 5, 1,16). Such results may throw some light on how the immature seeds of **prunus** are able to develop in the presence of relatively low concentrations of inhibitors.

Summary :

1. An enzyme extract prepared from seedlings of **Prunus armeniaca** is capable of breaking down the inhibitors of **Punus** seeds **in vitro.**

2. The activity of the cell free extract is lost by boiling suggesting that the breakdown of the seed inhibitors is not due to a thermostable non-enzymatic materials.

3. The inhibitory action of **Prunus** seed inhibitors, at relatively low concentrations, slightly stimulate the growth of the coleoptile sections.

4. The inhibitors of **Prunus** seeds are capable of antagonizing the promoting effect of the indole acetic acid **in vitro**.

The authors thank Prof. M.G.A. Hafez for his valuable criticism and discussion.

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ISOLATION OF CELLULOSE DECOMPOSING FUNGI FROM GARDEN SOIL

By

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I - INTRODUCTION

Decomposition of cellulose by microorganisms has been known since 1886, when Hoppe–Seyler placed filter paper together with some sewage in a flask and examined after four years, to find that about 57% of the filter paper had been digested. Obviously decomposition took place by anaerobic bacteria. Many workers, later on, proved that fungi can also decompose cellulose (Iterson, 1904; Kellerman and McBeth, 1910; Waksman, 1918; Fuller and Norman, 1942; Siu, 1951; Marsh, 1953; Nishizawa, 1955 ; Thomas, 1956; Husain and Kelman, 1958; and Abu Zied, 1962).

Most of the fungi that decompose cellulose had been isolated from cellulosic material. As far as the literature indicates, no attempt has been made to isolate cellulose-decomposing fungi from Egyptian soil. Consequently, the present work has been carried out to isolate fungi capable of decomposing cellulose from garden soil.

II - MATERIAL AND MTHOEDS

The following basal semisynthetic medium (Lilly and Barnett, 1951) has been used with varying the nitrogen source :

*Tanks are due to A. El Bayoumi for his assistance.

Cellulose powder	10	gms.
Nitrogen source	2	gms.
$KH_2 PO_4$	1	gm.
$Mg So_4 . 7 H_2O$	0.5	gm.
Fe^{+++}	0.2	mgm.
Mn^{++}	0.1	mgm.
Biotin	5	ug.
Thiamine	100	ug.
Agar	20	gms.
Distilled water to make	1	lt.

The nitrogen source was asparagine, sodium nitrate, ammonium sulphate or peptone. All media were adjusted to pH 6. Soil samples were taken from a place rich in humus under **Juglans** a tree grown in the Botanical garden of the Faculty of Science, Ain Shamas University, Abbassia, at three different levels, one at the soil surface, the second 25 cms. and the third 50 cms. below soil surface. Ten gms. of soil were taken at each level under aseptic conditions. Four samples were taken from each level. Each sample was shaken with 90 mls. of sterilized water for 15 minutes and suitable dilutions were made. Five replicates, each one ml., were plated on the different experimental treatments of medium. Counts were calculated during a period of 2 weeks incubation at 30°C. to obtain number of organisms per one gram of oven dry weight of soil.

III - RESULTS AND DISCUSSION

The results (Table I) show that the maximum count of cellulose decomposing - fungi was obtained on growing the fungion a medium containing amonium sulphate as nitrogen source. Counts were significantly higher than on media containing peptone, sodium nitrate or asparagine. Similarly the count from surface soil is significantly higher than from soil below the surface on any of the nitrogen containing experimental media.

Table 1

The average of the total count per one gram dry soil on different nitrogen-containing media at different soil levels.

Soil levels	Medium containing nitrogen in the from of			
	Asparagine	Sodium nitrate	Ammonium sulphate	Peptone
Surface	1560	2410	5420	4590
25 cms. below	1090	1670	2060	1860
50 cms. below	680	880	1100	1000

Twenty seven different species of cellulose - decomposing fungi could be isolated from the different soil samples.

The present worker could identify the following genera or species from the different isolations :

Alternaria tenuis
Aspergillus flavus
A. fumigatus
A. glaucus
A. niger
A. terreus
Chaetomium sp.
Cladosporium herbarum
Cunninghamella echinulatus
Fusarium semitectum
F. solani
Helminthosporium sp.
Macrosporium sp,
Penicillium funiculosum
P. glaucus
Stemphylium sp.
Trichoderma sp.

Garden soil rich in humus has proved to contain a considerable numbe of celluose - decomposing fungi. Their number diminishes with depth and are most abundant at the surface of the soil. Several workers concluded similar results concerning the total count of fungi

whether cellulose decomposers or not (Waksman, 1916, 1944 and Cobb, 1932). It seems that most of the cellulose - decomposing fungi isolated from the experimental soil samples utilize ammonium nitrogen better than nitrate or organic nitrogen as their number was greatest on media containing the former than media containing the latter nitrogen sources.

SUMMARY

Celluose - decomposing fungi were isolated from garden soil rich in humus. Isolations were made on a semisynthetic medium containing different nitrogen sources.

A great number of the cellulose- decomposing fungi are present at the surface of the soil and their number decreases with depth.

Most of the isolated cellulose- decomposing fungi prefer ammonium nitrogen better than nitrate or organic nitrogen.

Eleven genera of the isolated cellulose - decomposing fungi could be identified.

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ON THE FUNGAL FLORA OF THE EGYPTIAN DESERT IN SUMMER

By

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INTRODUTION

The study of the microbiology of the arid zones is now of increasin interest. Michoustine (1956) in USSR, Pochon, Barjac and Lajaudie (1957), in France, Montasir, Mostafa, and Elwan (1958), Elwan and Mahmoud (1960), in Egypt, and Sasson and Daste (1961), in Morocco, have dealt with various aspects of the microbiology of the arid zones.

A note on the bacterial flora of the Egyptian desert in summer has been published by Elwan and Mahmoud (1960). They investigated two localities at Suez Road region (K.28 & K.58) holding three dominant plants namely, **Citrullus colycinthus, Artemisia monosperma,** and **Hyoscyamus muticus**. The present investigation is dealing with the mycoflora of the soil in these two localities and of the rhizosphere of such plants, in an attempt to find out the relation between soil droughtness and the abundant mycoflora, and to give more evidence of the significance of the root region as a microhabitat on the distribution of fungi. Attention has also been made to find out whether abundant mycoflora in both soil and rhizosphere are represented in active forms on the root surfaces of xerophytes in the dry season.

The desert region is the widest phytogeographical region in Egypt embracing a total area of about 960,000 sq. kms. The air temperature of this desert, varies between 13.5 and 30.0°C. Maximum values of 40°C

or 45°C at 2-3 p.m. in summer, have been recorded (Montasir, 1954). This desert region is relatively dry and sand storms are common. Coarse and fine sand form most of the constituents of the desert soil.

The localities under investigation, show a low humus content ranging from 0.093 to 0.097%, an alkaline soil reaction of pH 8.5, a calcium carbonate content of 2.7% at k. 28, and of 7.1% at k. 58, and saturation capacity percentages of 1.0% at k.28, and of 4.8% at k. 58.

With regard to macrovegetation, the two localities show similarities except in the identity of the dominant species. At k.28, **Artemisia monosperma** predominated and at k. 58, **Citrullus colycinthus** and **Hyoscyamus muticus** were the dominant species.

METHODS

Soil and rhizosphere sampling was carried out aseptically. A box of 1 x 0.5 m. sprayed from inside with 4% formalin and containing all the sterilized manipulations, was vertically located against the wind direction, with its only opened side towards the chosen plant. The root system of the plant had been carefully excavated down to the growing point, shaken to get rid of the superfluous sand (Webley et al. 1952) and then quickly transferred to a sterilized conical flask of 250 ml. capacity containing 100 ml. sterile distilled water. The flask was shaken for one minute and transported to the laboratory for investigation. Few cms. far from the root, the soil was dug to make a hole of about 50 cm. depth and 50 cm. diameter. Samples of soil at horizons of 10, 20, 30 & 40 cm. depths were taken horizontally by sterile soil spatula and transferred directly to sterile wide mouth bottles. A sample of about 2 kg. was taken from the hole along the upper 40 cm. and this was considered as "total" sample.

Rhizosphere fungal counts were made by the dilution plate technique using Czapek's agar medium to which 1% yeast extract was added and the pH was adjusted to 6.5.

Soil fungal counts were made on the same medium but using the soil plate technique (Warcup 1950). A standardized sterile spatula was used to spray a known weight of soil (previously passed through a 2 mm. sieve) on each plate. The medium was then poured on the sprayed soil. Four replicates were made for each count. Percentage frequencies of fungi appearing on the plates were calculated. Incubation temperature was 30°C throughout the investigation. Counting was made 7 days after incubation.

To find out whether the most common fungi are repesented in active forms on the root surfaces, the roots were picked up from the conical flasks and subjected to a series of washing in sterile distilled water. Five washings were made, each recieving two minutes by hand. The roots were then aseptically cut into pieces of 3-4 cm. long and inserted on the surface of Czapek's agar plates. Observations and isolations were made 7 days after incubation at 30°C.

Fungi of low frequency isolated from the rhizosphere and from washed roots were sedimented together with other fungal isolates, at the Egyptian National Research Council.

RESULTS AND DISCUSSION

Rhizosphere and soil fungal counts are given in Table I. The values of R:S ratio indicate a strong rhizosphere effect. Ranges of hundred thousands per gram rhizospheric sand and of ten thousands per gram soil, were recorded. The results give more evidencé for the significance of the rhizosephere as an influencing microhabitat in the desert community in the dry season. A similar conclusion has been obtained in investigating the bacterial flora of these plants (Elwan and Mahmoud 1960). The striking observations were that **Aspergilli**, **Penicillia**, and **Fusaria**, were predominating on the counting plates (Table II). These fungi, being strongly sporulating organisms, may represent a natural response to the coditions prevailing in the dry season. Their possible occurrence in active forms on the root surfaces, has been evidenced by their isolation from serially washed roots (Table III). It is supposed that spores have been washed out during serial washings and the

mycelial fragments are still sticking to the root surfaces. Although this technique does not afford a quantitative estimation of these active

Table I : Rhizosphere (R) and Soil (S) fungal counts and rhizosphere: soil ratios (R:S).

	Fungalcounts		
	(R) No/gm rhizospheric soil	(S) No/gm	R:S ratio
Citrullus colycinthus	920,000	12,500	73.6
Artemisia monosperma	500,000	12,500	40.0
Hyoscyamus muticus	550,000	11,110	49.5

forms, yet it is believed that it affords an evidence of the presence of **Aspergilli**, **Pencillia**, and **Fusaria** in active forms on the root surfaces. This finding is of great importance, since it may evaluate the significance of these microorganisms in contributing for the ability of desert plants to endure drought Drought resistance of xerophytes is usually accounted for by many physical and physiological factors, and the microbiological factor is still underestimated. The possibility of the supply of water to higher plants by microorganisms, might be through decomposing the organic matter of the sloughed off parts of the roots and releasing water as a result of the reaction. It is felt that a quantitative estimation of the active forms of microorganisms in the rhizosphere of desert plants under droughty conditions, is necessary to evaluate the importance of this factor.

The abundance of **Aspergilli** and **Penicillia** in the desert soils

Table 2: Percentage frequency of **Aspergilli**, **Pencillia** and **Fusaria** on rhizospheric plate counts.

	% frequency			
	Aspergilli	**Pencillia**	**Fusaria**	Other fungi
Citrullus colycinthus	10.8	36.6	38.0	14.6
Artemisia monosperma	8.8	53.3	27.0	10.9
Hyoscyamus muticus	37.8	25.0	18.7	18.5

Table 3 : Fungi isolated from serially washed roots.

	Fungi isolated
Citrullus colycinthus	Aspergillus flavus, A. niger, A. spp. Penicillium spp., Fusarium spp.
Artemisia monosperma	Aspergillus terreus, A. flavus, A. niger, A. spp., Penicillium spp., Fusarium spp.
Hyoscyamus muticus	Aspergillus terreus, A. flavus, A. niger, Penicillium spp., Fusarium spp.

(Table IV), is rather astonishing. In some soils, only **Aspergillus** could be isolated on the media used. The possibility of the presence of other fungi needing special requirements to be detected in the soil and in the rhizosphere, needs verification by further extensive investigations using various types of media.

With regard to the specificity of microorganisms in the rhizospheres, **Fusaria** have only been isolated from the latter in this investigation. They were not recorded in soils studied. The invalidity of this specificity, among desert plant rhizospheres, might be evidenced by the similarity of the most abundant microorganisms in both the rhizospheres and she soils in previous investigation; **Fusarium equiseti**, in particular, has been isolated from some desert soils (Montasir, Mostafa, and Elwan 1958). However, it is necessary to investigate the rhisosphere of desert plants, using various types of techniques and media, before giving a final conclusion, regarding specificity.

As for the effect of depth on the number and distribution of fungi in desert soils (Table IV), it might be noticed that the first 20 cms. depths are the active sites below which the numbers more or less show a decrease.

Table IV. Effect of depth on both fungal counts and their distribution using soil plate method. (SA = **Atremisia** soil; SH = **Hyoscyamus** soil; Tot. = total)

Depth	Count No/gm soil	Distribution of fungi (%) **Aspergilli**	**Penicillia**	**Fusaria**
SA Tot	12,500	100.0	—	—
SA 10 cm.	10,000	100.0	—	—
SA 20 cm.	23,000	100.0	—	—
SA 30 cm.	5,000	100.0	—	—
SA 40 cm.	11,000	100.0	—	—
SH Tot.	11,110	88.0	12.0	—
SH 10 cm.	9,000	61.2	38.8	—
SH 20 cm.	8,500	40.0	60.0	—
SH 30 cm.	3,500	100.0	—	—
SH 40 cm.	2,500	100.0	—	—

SUMMARY

An investigation of the mycoflora of some desert plants and soils, in the dry season, has been carried out. The results showed evidence as for the significance of rhizosphere as an influencing microhabitat in the desert community. Abundance of **Aspergilli**, **Penicillia**, and **Fusaria** in the rhizospheres has been recorded. **Aspergilli** were the only fungi isolted from one soil on the medium used, and **Aspergilli** and **Penicillia** were only recorded in the second soil studied. **Fusaria** have only been isolated from rhizospheres but not from soils. **Aspergilli**, **Penicillia**, and **Fusaria** were isolated from serially washed roots indicating their occurrence in active forms on the roots. The possible significance of these in contributing for the ability of the desert plants to endure summer drought has been discussed. Demonstration of the first 20 cms. depths as the active sites for fungal development has been notified.

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STRAIGHT GROWTH TEST FOR HRMONES AND INHIBITORS USING SOME EGYPTIAN GRAMINEOUS PLANTS

By

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It is useful for the growth research work to find out some suitable Egyptian gramineous plants for assaying the activity of growtq promoting and inhibiting substances. We have found great difficulties in obtaining and germinating Avena grains as a test object. Pure strains of **Hordeum vulgare** L., **Zea Mays** L., **Triticum vulgare** vill., **Sorghum vulgare** Pers. and **Oryza sativa** L. were obtained from the Egyptian Ministry of Agriculture for the present work.

Method :

The grains of the previous plants are first soaked in water for 3 – 5 hours at laboratory temperature. They are then planted in coarse sand in wooden or plastic boxes. Initially the sand is wetted, care being taken to prevent both excess and dificit of water since both cause poor growth of the material. The grains are sown approximately 0.2 – 0.5 cm. below soil surface. The boxes are placed in complete darkness in an electric incubator at about 26 – 28°C. The grains are evenly watered every day. The period from the time of planting until the coleoptile lengths are suitable for the test varies according to the different species of plants and also differs slightly in the same species.

The coleoptile cutter used to excise the sections is nearly the same as that of Bentley (3). The boxes are exposed to phototropically

inactive light (yellow) for the last 12 – 15 hours before the test, to suppress the growth of mesocotyls. The coleopile test is carried out under condition of red light.

Ten coleoptiles of uniform length are placed side by side on a graduated wet slide, with their tips just at the edges of the slide. The slide is then upturned on the cutting edges of the cutter. Three mm. is rejected from each coleoptile tip and 10 mm. or 5 mm. sections next to this tip are cut between the two razors of the cutter. The first leaf is left in the coleoptile section. These sections are transferred to the surface of the solution to be tested. The sections are left in darkness to grow in an electric incubator (about 28°C) for about 18—22 hours. The sections are then measured with a photographic enlarger (magnification of 5X) and the enlarged images are measured with a plastic ruler to the nearest mm. The mean length of the 10 sections is calculated.

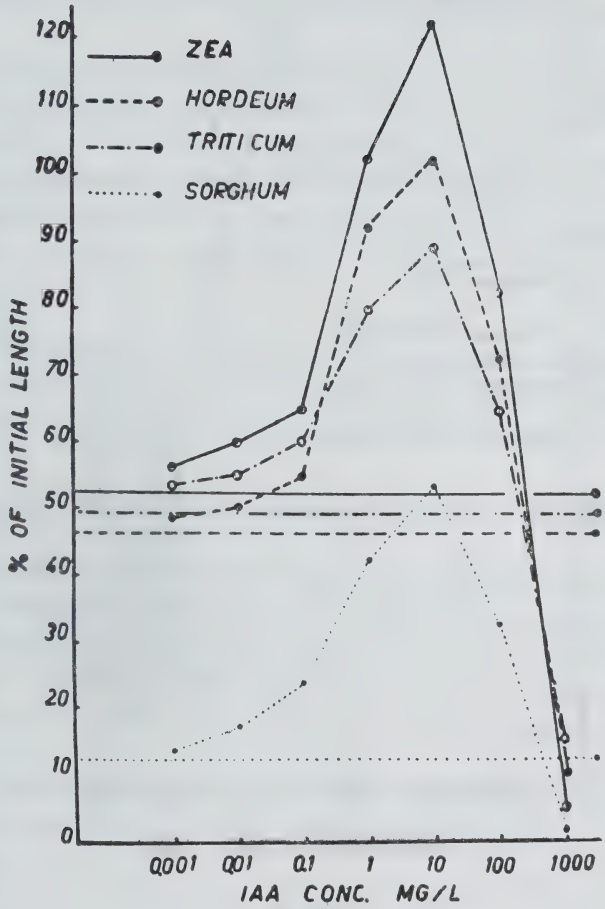
Under the above mentioned conditions, the coleoptiles of **Oryza sativa** are ruptured before they reach the suitable length ready for the test and so we are unable to carry out the test using these coleoptiles.

The growth activities of the different coleoptile sections are examined using different concentrations of indoleacetic acid (IAA) as a plant hormone and coumarin as a natural growth inhibitor.

The activity curves for the different coleoptile sections in IAA and coumarin are expressed graphically in Fig. (1) and Fig. (2) respectively.

Results :

It is clearly shown that relatively high coucentration of IAA (1000 mg/l) has an inhibiting action on the growth of the coleoptile sections of the four plants, as being compared with their controls. Maximum growth is obtained at 10mg/l of indoleacetic acid in all of them. The shape of the activity curves is more or less similar for all of them, but the sensitivity of the coleoptile sections differ in the


ZEA
HORDEUM
TRITICUM
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% OF INITIAL LENGTH
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110
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70
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50
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0.001
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1
10
100
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IAA CONC. MG/L

Fig. 1

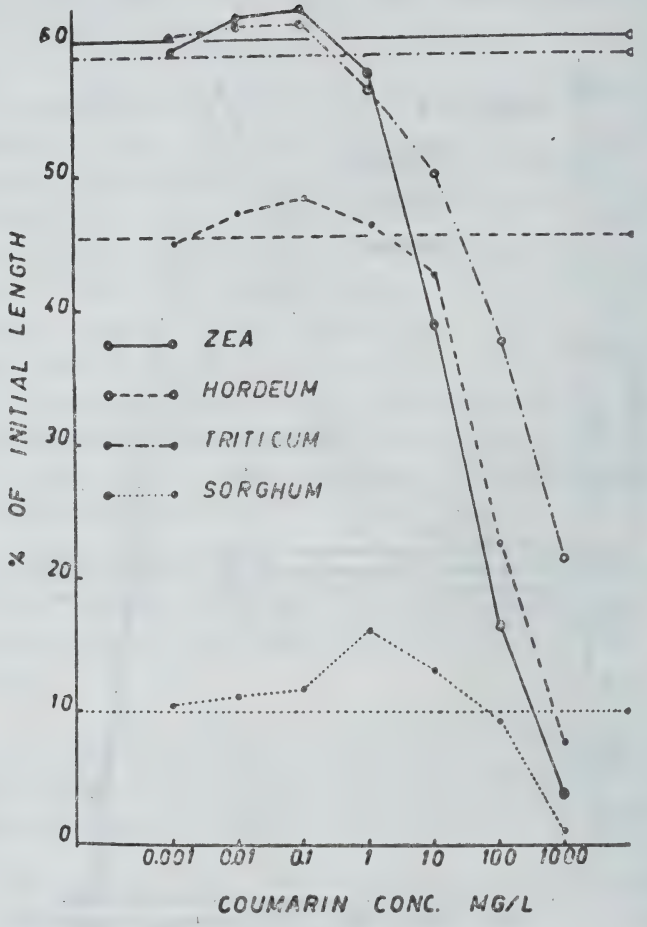
60
50
40
30
20
10
0
% OF INITIAL LENGTH
ZEA
HORDEUM
TRITICUM
SORGHUM
0.001
0.01
0.1
1
10
100
1000
COUMARIN CONC. MG/L

Fig. 2

different plants. The maximum response to IAA is obtained in case of **Zea** coleoptiles, followed by **Hordeum** then by **Triticum** and the minimum response is shown in case of **Sorghum** coleoptiles (Fig. 1).

In case of coumarin, the natural growth inhibitor, on the other hand, its inhibiting action is more effective on the growth of **Triticum**, followed by **Zea** and Hordeum coleootile sections respectively, while it is of minimum value in case of **Sorghum**. For this reason, the **Sorghum** coleoptiles are not recommended as a testing object for the growth inhibitors, while those of **Triticum**, **Zea** and **Hordeum** can be used.

The minimum growth rate of the coleoptile sections in the control dishes i.e. without IAA or coumarin is in case of **Sorghum** followed by that of **Hordeum**, **Triticum** and **Zea** respectively.

Sensitivity of the First Internode Sections to Indoleacetic Acid.

It has been found during the germination of **Zea Mays** grains for the previous test, that the first internode shows marked straight growth, suggesting that it may be used as a good test object for assaying the growth resgulating substances. Similar test have been carried out by Nitsch and Nitsch, 1956 (6) using the first internodes of oats.

The following experiment was carried out to find out whether the first internode of **Zea Mays** may be used as an object for bioassay.

a) Sections of 1 cm. long, excised from the upper part of the first internode (about 2.5 cm. long) of Zea seedlings are allowed to grow on the surfaces of different concentrations of IAA.

b) In a second set, sections of 1 cm. are taken from the upper part of the first internode of about 4.5 cm. long are also left to grow in different concentrations of IAA.

c) In a third set, sections of 1 cm. long are excised from the lower portion of the first internode are also left to grow in different dilutions of IAA

Control dish of distilled water without IAA is examined with each of the previeus sets.

The activity curves of the three sets are shown graphically in Fig. 3.

It is cleary shown that the activity growing zone of the first internode is restricted to the upper part and so sections taken from the lower part show nearly no growth. The shorter the internode is, the larger the rate of the growth.

It has been found that the length of the first internode of **Zea Mays** is not even and so it is difficult to select material of uniform length for assay. The respnnse of the sections in the same concentration is not also uniform. These observations suggest that although the first internode of **Zea Mays** seedlings shows a marked growth, it is not a good testing object for bioassay.

Study of some Factors Affecting the Response of the Bioassay to IAA

It has been observed that the time necessary for the **Hordeum** coleoptiles to reach the suitable length for the test is relatively short. It has been also found that the length of the **Hordeum** coleoptiles ready for the test is even and so it is easy to select materials of uniform lengths. The response of the **Hordeum** coleoptile sections has been also found to be nearly uniform. So, the following experiments are carried out to find out the more suitable conditions for the straight growth test using **Hordeum** coleoptile sections.

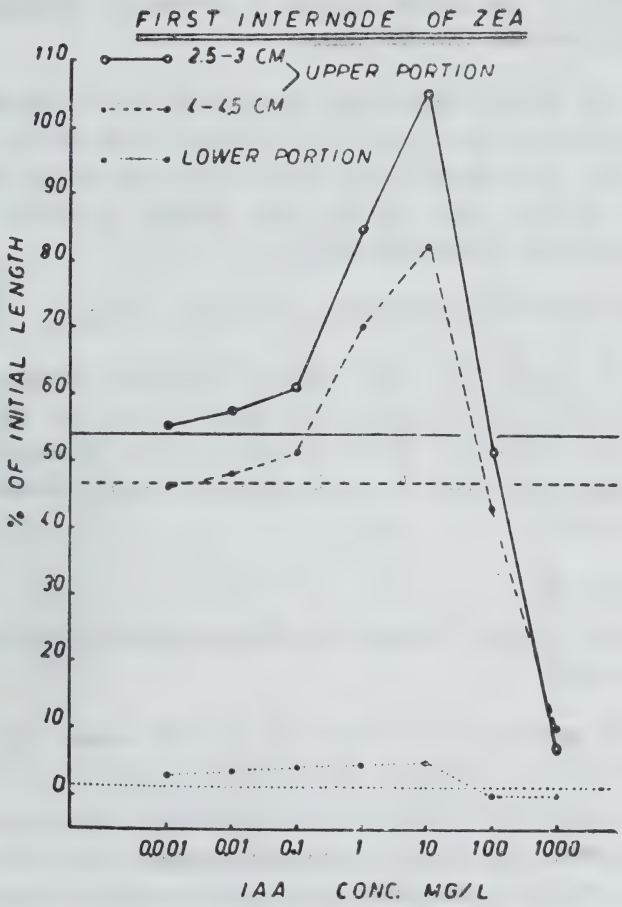
FIRST INTERNODE OF ZEA
2.5-3 CM
UPPER PORTION
4-4.5 CM
LOWER PORTION
% OF INITIAL LENGTH
110
100
90
80
70
60
50
40
30
20
10
0
0.001
0.01
0.1
1
10
100
1000
IAA CONC. MG/L

Fig. 3

Experiment 1

Effect of the Initial Length of Hordeum Coleoptile at the Test Time on the Growth Rate

In the follwing experiment, the growth rate of **Hordeum** coleoptile sections taken from coleoptile of different initial length excised from 3 mm. below the coleoptile tips of different initial length (1.5 – 1.7 cm.; 1.9 – 2.1 cm. and 2.4 — 2.6 cm.) are allowed to grow in different concentrations of indoleacetic acid.

The results are represented graphically in Fig. 4.

It is found that the shorter the initial length of **Hordeum** coleootile section is, the larger the growth rate, but the growth of the controls is also high in the younger stages. It is shown also that the younger and shorter the initial coleoptile length, the less uniformity is their growth.

Experiment II

Effect of the Position of the Coleoptile Sections on the Growth Rate

This experiment is carried out to find where one should cut the coleoptile sections to get the maximum response to the test solution.

Sections of 1 cm are cut at varying distance from the coleoptile tips of **Hordeum** (1 mm., 2 mm., 3 mm. and 5 mm.). The sensitivity of these different sections is examined using various concentrations of IAA. The results are represented in Fig. 5.

It is shown that the sensitivity of **Hordeum** coleoptile sections differs greatly according to their locations.

Sections cut 5 mm. below coleoptile tips are less sensitive than those excised 3 or 2 mm. below and the latter show less growth than those taken 1 mm. below the tip. One must refer to the fact that when the coleoptile sections of **Hordeum** are excised close to the tips, their growth is considerably high in the control dishes without added IAA.

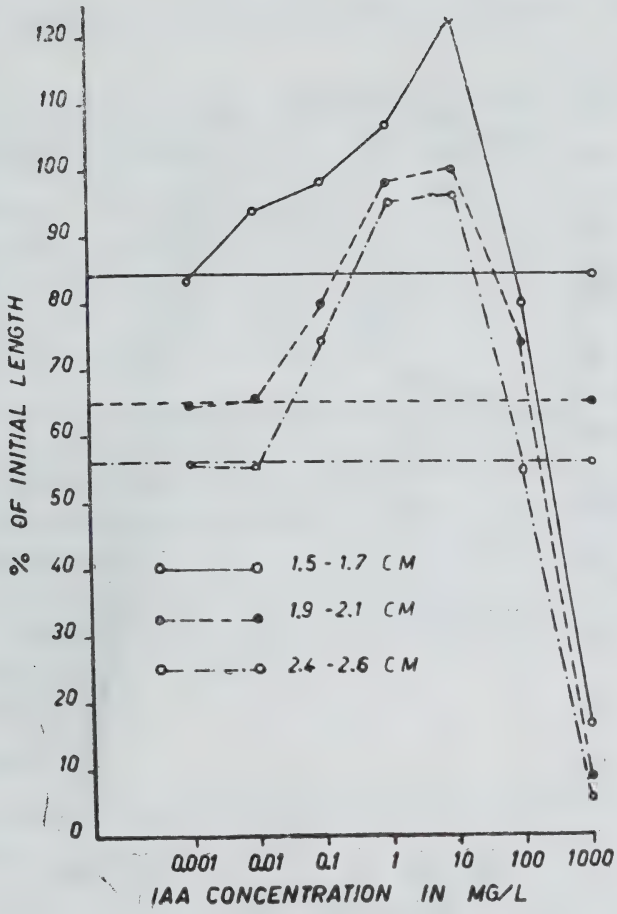
120
110
100
90
80
70
60
50
40
30
20
10
0
% OF INITIAL LENGTH
1.5 - 1.7 CM
1.9 - 2.1 CM
2.4 - 2.6 CM
0.001
0.01
0.1
1
10
100
1000
IAA CONCENTRATION IN MG/L

Fig .4

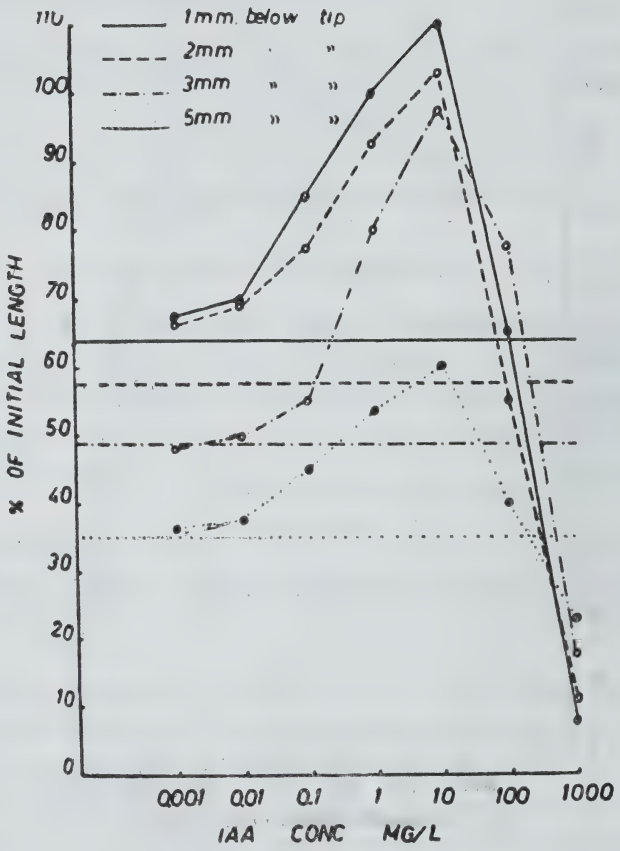
1mm. below tip
2mm " "
3mm " "
5mm " "
% OF INITIAL LENGTH
110
100
90
80
70
60
50
40
30
20
10
0
0.001
0.01
0.1
1
10
100
1000
IAA CONC MG/L

Fig. 5

Experiment III

Time Effect on the Growth Rate of Coleoptile Sections of Hordeum

It is important to find out the suitable time after which one should measure the elongation of the coleoptile sections.

Hordeum coleoptile sections of 1 cm. cut 3 mm. below the tips are placed in different concentrations of IAA (10 mg/l, lmg/l and 0.1 mg/l). Their lengths are measured after 2, 4, 6, 8, 10, 24 and 48 hours. The results of their growth together with that of the control are represented graphically in Fig.6.

It is shown that most of the growth occurs in the first 8 hours and then the slope of the growth rate decreases gradually by the time. When the coleoptile sections are kept longer in the solutions, the growth rate of the controls (without IAA) increases gradually, thus reducing the difference between the rate of growth with and without indoleacetic acid. For this reason, it is not recommended to leave the coleoptile test for relatively longer time. In addition to that, the long term experiments may be interfered with by baceterial and fungal contaminations

Experiment IV

Effect of Initial Length of Hordeum Coleoptile Sections on the Rate of Growth.

Sections of 1 cm. and 0.5 cm. are excised from 3 mm. below the tip of uniform lengths of **Hordeum** coleoptiles. The response of these sections to various concentrations of indoleacetic acid is studied.

The activity curves of both types ef sections (1 cm. and 0.5 cm). are represented graphically in Fig. 7.

It is clear that the coleoptile sections of 0.5 cm. initial length are more sensitive to IAA than those of 1 cm., although both are excised from coleoptiles of uniform length. It is also observed that the longer the initial length of the **Hordeum** coleoptile section, the less straight they are. This is not recommended in the straight growth

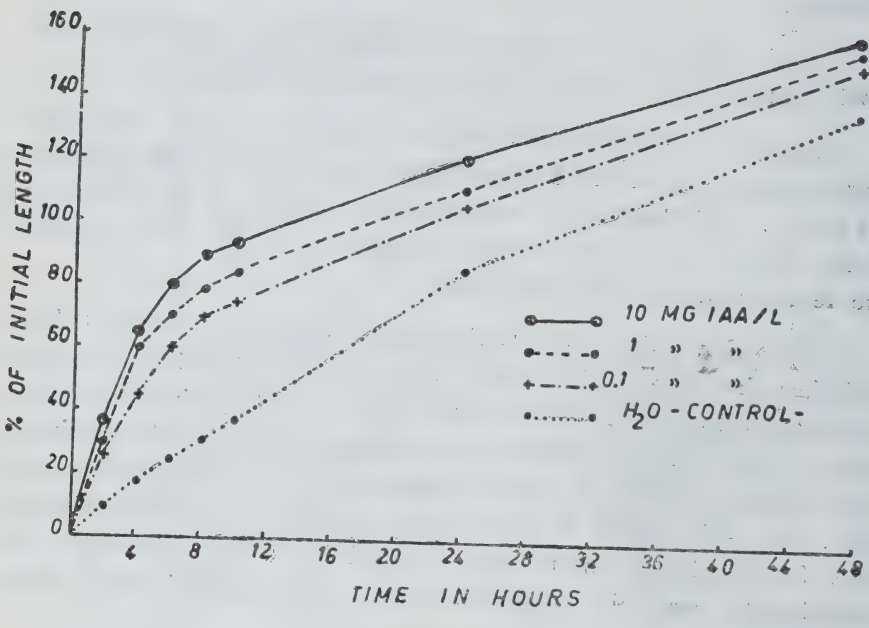
% OF INITIAL LENGTH
160
140
120
100
80
60
40
20
0
4
8
12
16
20
24
28
32
36
40
44
48
TIME IN HOURS
10 MG IAA/L
1 " "
0.1 " "
H_2O - CONTROL

Fig: 6

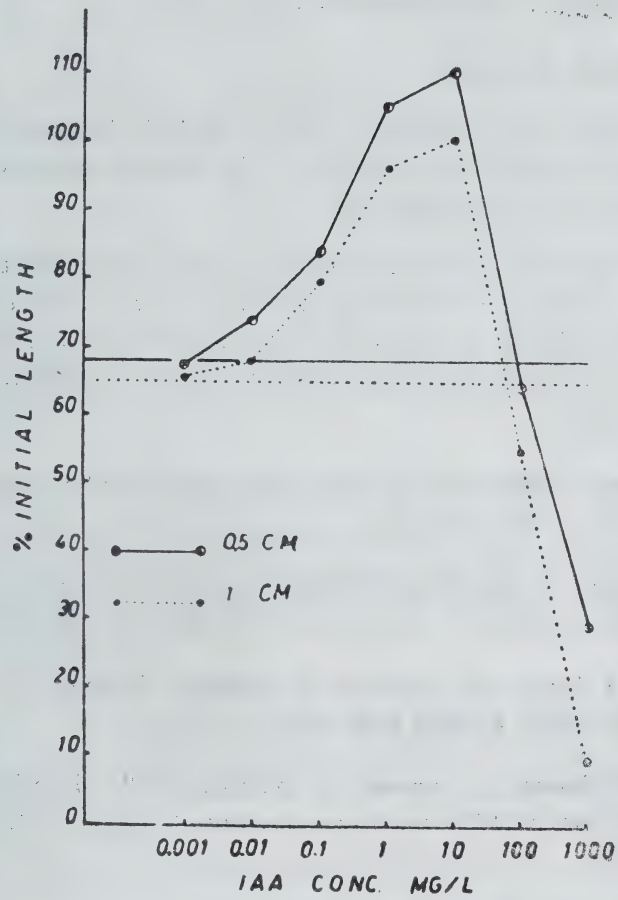
% INITIAL LENGTH
110
100
90
80
70
60
50
40
30
20
10
0
0.5 CM
1 CM
0.001
0.01
0.1
1
10
100
1000
IAA CONC. MG/L

Fig. 7

test. For these reasons, an initial length of 0.5 cm. **Hordeum** coleoptile section is preferred if being compored with 1 cm.

Conclusions and Summary

One of the most suitable and reliable methods for assay the activity of plant hormones and inhibitors is the straight growth of **Avena** coleptile sections. (7,8,4,1,5,3, & 6).

In the present investigation, five Egyptian gramineous plants are examined to find out whether they can be used as a test object for assaying the activity of the growth regulating substances. These plants are: **Hordeum vulgare**, **Zea Mays**, **Triticum vulgare**, **Sorghum vulgare** and **Oryza sativa**.

The steps of the test as well as the results and conclusions can be summarized in the followings.

1. Grains of the different plants are soaked in water for 2— hours and then planted in coarse sand in wooden or plastic boxes.

2. The boxes are incubated in complete darkness at 26-28°C and they are evenly watered every day.

3. The boxes are exposed to phototropically inactive yellow light for the last 12-16 hours before the test, to suppress the growth of mesocotyls.

4. The coleoptile test is carried out under condition of red light.

5. A cutter is used to cut equal sections from uniform plant organs.

6. The first leaf is left inside the coleoptile sections since their presence has a stimulatory effect on the rate of section growth(3).

7. Ten sections are transferred to the surface of each solution to be tested.

8. Sections are then incubated (26 - 28°C.) for a suitable time after which they are measured by a photographic enlarger (magnification 5X) with a plastic ruler to the nearest mm, and the mean length of the 10 sections is calculated.

9. Coleoptile of **Oryza sativa** are ruptured before they reach the suitable length ready for the test and so they cannot be used as a test object under the above mentioned conditions.

10. The activity curves of **Zea**, **Hordeum**, **Triticum**, and **Sorghum** coleoptiles, using various concentrations of IAA, are more or less similar, but the response differs in the different plants.

The maximum response to IAA is shown in case of **Zea** coleoptiles; followed by **Hordeum**, then by **Triticum** and lastly by **Sorghum** coleoptiles.

11. The inhibitory action of coumarin, a natural growth inhibitor, is more effective on the coleoptile sections of **Triticum**, followed by **Zea**, then by **Hordeum**. The minimum response to coumarin is in case of **Sorghum** suggesting that it is not suitable as a testing object for assaying inhibitors.

12. The maximum growth of coleoptile sections in the control dishes, without IAA or coumarin, is obtained in case of **Zea**, followed by **Triticum**, then by **Hordeum** and lastly by **Sorghum** coleoptiles. Such difference is possibly due to the fact that the native auxins and nutrients vary from one plant to another.

13. **Hordeum** coleoptiies are found to be a suitable testing object for assaying the activity of plant growth substances for the following reasons :

a. They reach the suitable length ready for the test in relatively short time.

b. The length of the coleoptiles ready for the test is even and so it is more easy to select material of uniform length for assay.

c. The response of the sections to a given solution is nearly uniform.

14. The first internode of Zea Mays seedling is investigated as a testing object for bioassay. Its actively growing zone is restricted to the upper part. The shorter the internode is, the larger the rate of growth. It is found that the length of the first internode is not even and so it is difficult to select materials of uniform length of the test. The response of the internode sections in a given solution is not also uniform. These results suggest that the first internode of Zea Mays seedling is not recommended as a testing object for bioassay. These results are contradictory to the results obtained with the first internode of oat (6).

15. Some factors affecting the magnitude of the response of the Hordeum coleoptile to IAA are investigated. These are :-

a) Effect of Initial length of Hordeum Coleoptile Sections at the Test Time on the Growth Rate.

It has been found that sections taken from younger and shorter initial coleoptile lengths show more growth than those excised from older and longer ones, but the growth rate of the former is not uniform. For this last reason, coleoptiles of relatively shorter and younger initial lengths are not recommended.

b) Effect of the Location of the Coleoptile Section on the Magnitude of the Growth

It is observed that coleoptile sections excised very close to the tip are more sensitive, that is because the actively growing zone of the coleoptile is located near the tip. So, coleoptile sections are to be cut from zone nearer to the morphological tip to get more growth rate.

c) Length of Time of the Coleoptile Sections in the Test Solution.

Most of the growth of Hordeum coleoptile sections takes place during the first 8 – 10 hours. As the coleoptile sections are left for a

longer time, the difference between the growth rate with and without IAA is greatly reduced. It seems probable that by the time, a physiological tip is regenerated at the morphological apex of each coleoptile sections in the control (without IAA) and so the rate of growth increases due to the new hormone supply produced by the new tip. For this reason, it is not recommended to leave the coleoptile sections for relatively longer time in the test solution.

d) Effect of the Initial length of Hordeum Coleoptile Sections on the Rate of Growth.

It has been found that coleoptile sections of 0.5 cm initial length are more sensitive to IAA than those of 1 cm. Those of 1 cm. initial length show more curvature during growth than those of 0.5 cm. For these two reasons, sections of 0.5 cm. initial length are more recommended for assay.

We thank Prof. M.G.A. Hafez for his constructive criticism and valuable discussion.

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THE OCCURRENCE OF FUSARIUM WILT OF PUMPKIN IN EGYPT

by

Y. A. YOUSSEF

Introduction

Fusarium spp. have been reported to cause vascular wilt to several cucurbit plants, Leach (1938), Mc Keen (1951) and Owen (1955). In the summer of 1960 plants of pumpkin (**Cucurbita** moschata Duch.) in some localities in the vicinity of Cairo were severely affected with a wilt disease. Isolations from diseased seedlings consistently yielded a fungus identified by Booth (Commonwealth Mycological Institute, Kew) as **Fusarium solani** (Mart.) Sacc.

The present work aims at studying the symptoms of the disease and the susceptibility of six cucurbit plants, as well as, the cultural characteristics of the pathogen as being recorded for the first time in Egypt, Melchers (1931, 1932), Brooks (1953) and Shaw (1958).

Materials and Methods

Single spore culture of the fungus were made from diseased seedlings taken directly from the field. They were established and maintained on Czapek's medium. Pathogenicity tests were made in soil inoculation experiments using six cucurbit plants namely, pumpkin, sweet melon, cucumber, vegetable marrow, water melon, and hairy cucumber. Cultural characteristics were also studied.

Experimental Results

1 — Soil inoculation experiments

Inoculation experiments were done either by dipping washed roots

of healthy seedlings in a spore suspension of the fungus and transplanting the seedlings in sterilized non-inoculated pots or by sowing surface-sterilized seeds in sterilized pots receiving a spore suspension of the fungus. Consequently, pots containing clay loam and sand in the ratio of 2 1 were prepared and autoclaved at 2.5 atmospheres for 2.5 hrs. The sterilized soil containing pots were divided into two lots, one was inoculated with a heavy spore suspension of the fungus while the other lot was left uninoculated to serve as control. Each lot was sown with surface sterilized seeds. Thirty seeds weré used for each cucurbit plant. The results showed that only pumpkin seedlings were highly susceptible to the disease. This indicated that the pathogen was specific only to its original host, when such host was in the seedling stage, or in the form of older plants.

Pumkin seedlings showed a high percentage of infection as all emerged plants were diseased. Inoculation of soil in pots containing pumpkin plants with **Fusarium solani** resulted in 100 per cent kill within 20 days. The low percentage of emergence showed that most seedlings were killed prior to emergence i.e. during the pre-emergence stage.

SYMPTOMS OF THE DISEASE

One of the first symptoms is a decreased growth rate of seedlings; usually the foliage changes from green to yellow in the oldest leaves first. It is characterized by a rapid yellowing and wilting of the cotyledons. The leaves become mottled and later yellow or even white as compared with that of the control (Fig. 1).

Occassionally the discoloured leaves droop downward at the edges (Fig. 2). Many seedlings become infected and killed before they emerge. Plants of any age from seedlings to those in full bloommay suddenly wilt and die. Symptoms, in older plants are a change in leaf colour, mottling, and the wilting of the entire plant which soon follows.

Yellowing and mottling appear first in the oldest leaves and extend upward into successively younger leaves. Usually the entire plant wilts and dies before the youngest leaves become yellow. The vascular tissues of the roots, stems, and petioles of all wilted plants

have a brown to dark brown discolouration (Fig. 3). Wilting is another characteristic symptoms, often affecting the entire plant when infection is severe. During this study wilting preceded the death of all the plants. Wilting may occur suddenly or over a period of 5 days, but once it has occurred the plant tissues gradually dried.

Cultural characteristics

1 — On Czapek's agar

The fungus grow rapidly, producing white aerial mycelium in young cultures. As the fungus aged, the substratum and sometimes the aerial mycelium assumed various shades of pale yellow to yellowish cream. Macroconidia were produced in great abundance in young culture. Microconidia and chlamydosporos were plentiful.

2 — On glucose — peptone agar.

The mycelium was confined to the surface of the medium and produced yellowish cream pigmentation. Microconidia were produced very greatly. Macroconidia were sparse and appeared in 8 - 12 days. Chlamydospores were plentiful.

3 — Spore - measuements

Measurements, made on 100 spores of each spore type from a 24 - day old culture grown on Czapek's agar at 28°C. (Fig. 4), were as follows :-

Microconida	(3 — 3.5 x 6 — 12)	microns.
Macroconidia	(3 — 6 x15 — 30)	microns.
Chlamydospore	(6 — 7 x 6 — 9)	microns.

4 — Description

The aerial mycelium is usually vigorous, white, and the substratum is yollowish cream. No sporodochia or sclerotia are in culture microconidia are abundant on aerial mycelium, apiculate, ellipsoid, elliptic or slightly fusiform, and mostly non-septate. Macroconidia are

plentiful, apiculate, and elliptic, or fusiform. Mostly 2 - septate macroconidia are rare. Chlamydospores are abundant, in young and older culture, single or in pairs, terminal or intercalary, globose or ovoid, and smooth. (Fig. 4).

DISCUSSION

The occurrence of vascular wilt disease caused by **Fusarium solani** of pumpkin for the first time in Egypt indicates that the disease is probably present among several other herbaceous plants. Soil inoculation experiments have proved the virulence of the pathogen as well as, its specificity on its original host, producing a typical wilting accompanied by a vascular discolouration.

Similar results were obtained by Owen (1956) in cross-inoculation test with wilt **Fusaria** from cucumber, watermelon and muskmelon. Each fungus was highly pathogenic on its original host. Planting of pumpkins, on heavily infested soil resulted in pre-emergence or post-emergence damping off of the young seedlings. The pathogen appeared to be much more virulent in the seedling stage than on older plants.

SUMMARY

A vascular wilt of pumpkin (Cucurbita moschata Duch.) was recorded. **Fusarium solani** (Mart.) Sacc., was isolated from the diseased plants and was found pathogenic to plants growing in soil inoculated with pure culture or both spore and mass isolate of the fungus. The syptoms of the disease include brown discolouration of the vascular system, yellowing and drooping of the foliage and wilting which is followed by death of the plant. The pathogen was found to be highly specific to its original host, as, it failed completely to infect any of the experimental curcubit plants at any stage of development.

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Shaw, C.G. (1958) Host Fungus Index for the pacific Northwest. II, Fungi, Washington Agric. Exper. Stat.

FIGURES

1 — Pumpkin seedlings 3 - weeks old, in soil inoculated with **Fusarium.**

2 — In non-inoculated soil.

3 — Longitudinal sections of diseased cucumber roots, showing browning of vascular bundles extending out into stems.

4 — Spores of **Fusarium solani** (Mart.) sacc.

A) Macroconidia.
B) Terminal chlamydospores.
C) Microconidia.
D) Intercalary chlamydospores.

Fig. 1

Fig. 2

Fig. 3

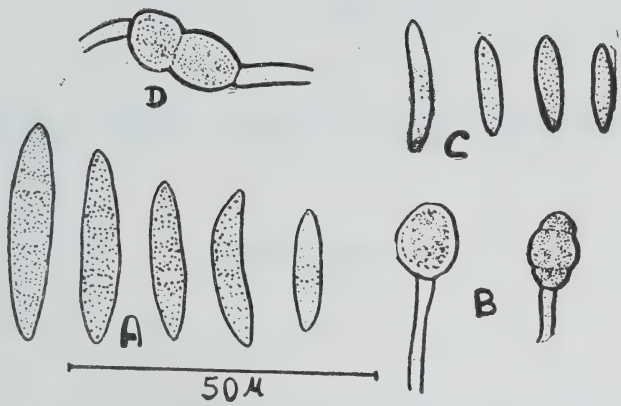

Fig. 4

AN ACCOUNT OF THE "SUDD" FLORA

By

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Assistant Professor of Botany, Faculty of Science

Ain Shams University.

Introduction

It was, through an excursion to the Upper Nile arranged by the Ministry of Public Works during the summer of 1954, that the writer got the opportunity to visit the "Sudd" region (Fig. 1). Two other members of the teaching staff of the Faculty of Science, Cairo University, namely, Prof. A.M. Migahid and Dr. Abd-El-Rahman Amin joined the excursion.

The data quoted in the present study were obtained from personal observations, and from references mentioned in the bibliography; and whenever possible, drawings of the botanical material were made by the writer from living specimens. The writer, in addition, proposed keys for the detection of monocotyledonous and dicotyledonous plants of frequent occurence in the "Sudd" swamps.

It is supposed that this trial is a basis for more detailed studies that ought to be carried out later.

The writer wishes to thank prof. A.M. Migahid for help and for reading the manuscript.

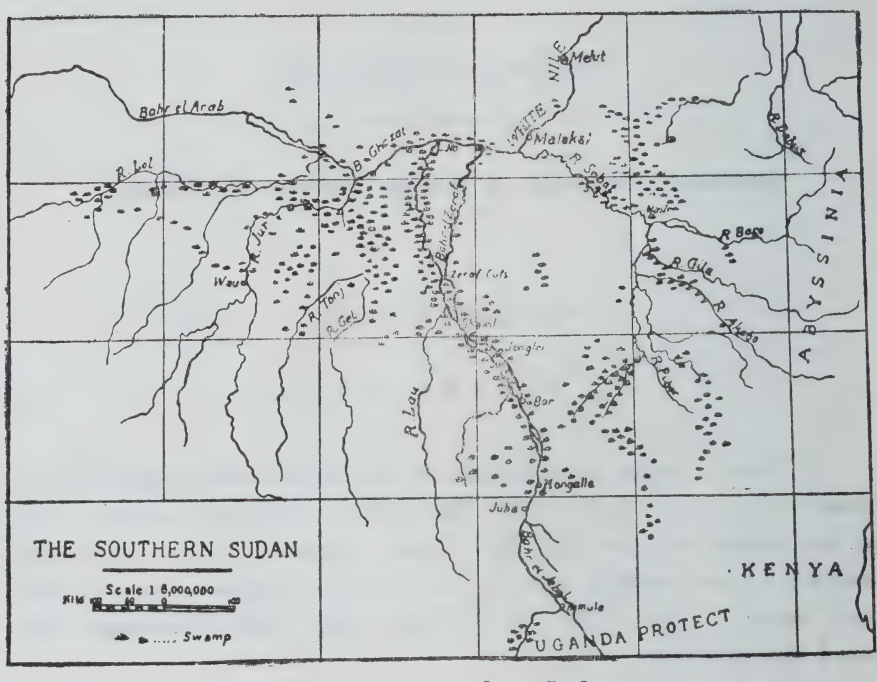

Fig.1 *The Southera Sudan,*

The "Sudd" Region

The "Sudd" region is an extensive swampy area in the Upper Nile (Fig. 2), occupying the basins of Bahr-el-Jebel, Bahr-el-Zeraf, Bahr-el-Ghazal and part of the Upper Sobat. The water-course of the river in these reaches is often blocked by floating masses of vegetation, which, being loostened by storms from the fringing vegetation are drifted downstream and arrested at one of the river bends. Other masses of drifted plants are added to the first-arrested one until a complete obstacle across the channel is established. The Arabic name of such obstacle is "Sadd".

Previously, towards the end of the nineteenth centuay, the formation of such "Sudd" obstacles was more frequent. Nowadays, their formation is prevented through regular passage of steamers along Bahr-el-Jebel from Khartoum to Juba. However, isolated masses of loostened swamp plants, but which are not large enough to form complete blocks, are always found.

The Principal Elements of Vegetation

The commonest plants found in the swamps are the following :-

1 — Cyperus papyrus Linn.

It is the most common species of the "Sudd". The aerial branches may reach a height up to 5 metres. The stems are smooth with basal sheathes. The diameter of the head runs to about three feet. The plants form more or less isolated clumps separated by a distance of about one foot. Old branches dry out continually and are replaced by new sprouts. There is rapid accumulation of plant remains and sedimentary material in the interstices of the rhizome mass.

Papyrus is found everywhere in the "Sudd" region. It develops on the surface of stagnant water in deep swamps as well as on the muddy banks of rivers and lagoons. It is also found on slightly elevated islets in the river. The roots are very soft and tender and so of little value for anchorage, and the plant depends mainly on its heavy basal mass of rhizomes.

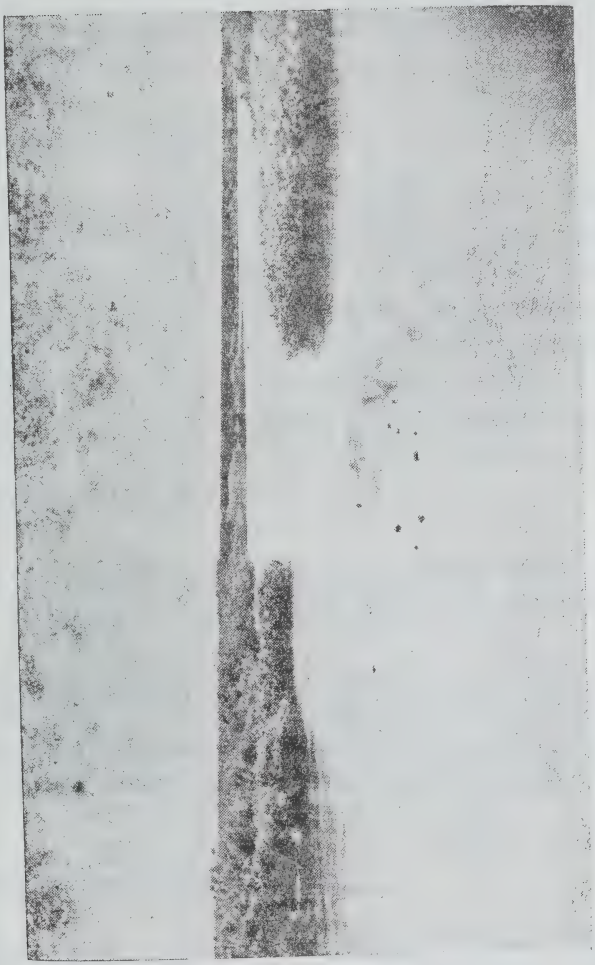

Fig .

Masses of Vegetation in Bahr-el-Jebel blocking the Water Course

Papyrus is a shallow-rooting plant; the roots being delicate and soft can not resist hard penetration and so the plant flourishes in easy-penetrable substrata as water and rich humus soils but not in heavy or dry soils

2. **Vossia cuspidata** Griff.

It is one of the principal constituents of the "Sudd". It is a large perennial grass with branching rhizomes, which either float on the water surface or spread horizontally on the ground surface. Sympodial aerial branches arise at the nodes of the rhizome and they may reach a height up to 2 metres. The roots of **Vossia** are not so tender as those of papyrus and can invade a relatively dry soil, and so the plants appear on dry grounds where papyrus cannot exist.

3. **Phragmites communis** Trin.

It is tall perennial grass with many jointed aerial branches. The leaves are shorter than those of **Vossia**, and are less uniform in breadth.

In the "Sudd", **Phragmites** always marks high ground where the bed of the swamp is considerably elevated. The plant is always firmly anchored to the ground and so never found floating on the surface of water.

4. **Typha australis** Schum. and Thonn.

It is a marsh plant with strap-shaped leaves. It is not very common in all parts of the "Sudd" region; but where found it is firmly anchored to the ground.

5. **Herminiera elaphroxylon** Guill. and perr.

It is a small tree with showy yellow papilionaceous flowers, and prickly branches. The stems are swollen at the base and consist of pith-like substance which is exceedingly light.

The plant is characterised, like most other swamp plants, by

rapid growth. It is met with in quiet places on the shores of open lagoons.

6. **Pistia stratiotes** Linn.

A very common tropical weed which floats freely on the water surface, sending dowu a tuft of feathery fibrous roots. The plant is found in quiet sheltered places, near shores of lagoons and along the banks of the main river and its branches where the water current is exceedingly slow. The plant propagates itself with great rapidity, covering vast areas of swamp in a relatively short time. The plants are frequently tangled in floating masses or little islands which are drifted away by the current. They are usually associated with **Nymphaea**, **Jussieua**, **Ceratophyllum**, Cyperus, **Phragmites** and **Herminiera.**

7. **Ipomaea aquatica** Forsk.

It is an important element of the "Sudd" vegetation which is hollow-stemmed, trailing or twining. It twines round the aerial branches of papyrus reaching the terminal umbels. The plant is aw important factor in binding together neighouring swamp plants. Where it does not find a support, attaches itself to the bank and extends for a distance in the river sending down tufts of fibrous roots at the nodes.

8 **Cissus ibuensis** Hook. F.

It is a herbaceous climber with trifoliate leaves. The plant is usually associated with **Ipomaea aquatica**, and attaches itself to a branch of papyrus or any other erect swamp plant.

9. **Vigna nilotica** Hook. F.

It is a common twining swamp plant usually associated with and has the same habitat as **Ipomaea aquatica** and Cissus **ibuensis.**

Geneal Distribution of Vegetation in the "Sudd" Region*

In order to arrive at a clear understanding and explanation of the observed distribution of the different species over the "Sudd" region, it is essential to know how far the environmental conditions prevailing in the region are favourable to each of them. Factors should not be isolated but have to be considered in their entire complexity. If in some area there is an environmental factor that does not permit the existance of one of the species, that species does not extend in that area, even though all other factors may be favourable. Thus the unfavourable factor results in restricting the distribution of the species. Getting rid of the competition of the excluded species, the remaining ones in the community are in a better situation to grasp the area and establish themselves on it. They can do so if they are able to tolerate all environmental conitions prevailing in the area.

Further, the conditions of the area may be favourable for a number of species, and yet only one or few of them are represented in it. They could all have been represented successfully where it not for competition among them. Competition is an inevitable result of their presence together in the same area. The presence of some of them creates new conditions that may not be toleratod by others, and consequently the latter are supressed. The conditions of the area, with the vegetation on it, may be greately different from the conditions that prevailed when it was bare.

In nature, the plants in a community mainly compete for water, nutrients or light. When present together, they often make demands for these factors in excess of the available supply. If, however, there is enough of any factor, no competition for that factor woulb take place.

In the swamps of the "Sudd" region, there is enough water and nutrients available to meet the requirements of all plants. Competition is therefore, essentially for light.

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* Refer to Migahid (1948).

Competion and limiting factors can account satisfactorily for the observed peculiar distributon of the different species in the "Sudd" region.

Prominent features of that distribution are the following: -

a) **Papyrus** is the dominent species in the "Sudd".

b) **Vossia** alone is observed to exend into running streams on either side for a considerable distance from the bank, as much as much as 10 metres sometimes.

c) **Phragmites**, and sometimes also **Typha**, occupy small elevated patches of land scattered in papyrus swamps.

Besides, other plants, of less importance are met with, either submerged e.g. **Ceratophyllym** and **Potamogeton**; or free floating e.g. **Pistia** and **Lemna**; or anchored floating e.g. **Nymphaea**.

KEY TO THE FAMILIES OF MONOCOTYLEDONS

A Ovary or ovaries superior

a Perianth present, or if absent or if much reduced or modified then flowers are arranged in spikelets with scale-like bracts

b Gynoecium (pistil) composed of 2 or more separate or almost separate carpels with separate styles and stigmas; plants mostly aquatic, sometimes marine..... POTAMOGETONACEAE

bb Gynoecium (pistil) composed of 1 carpel or of 2 or more united capels with free or united styles

c Perianth composed of separate calyx and corolla, the former often green, the latter usually petaloid, both series sometimes dry or transparent but never united into a single perianth tube ..... COMMELINACEAE

cc Perianth sepaloid or dry, usually very small inconspicuous, usually arranged in spadices or panicles often subtended by large spathaceous bracts, rarely solitary

d Leaves absent; minute aquatic herbs, the plant body reduced to a thallus-like frond with or without 1 or more pendent rootlets ..... LEMNACEAE

dd Leaves present, sometimes solitary

e Leaves alternate, sometimes radical or crowded; plants aquatic, floating stemless with a rosette of sessile leaves ..... ARACEAE

ee Leaves narrow, linear, flowers in dense cylindric spikes with female flowers below, male flowers above; ovary 1-locular with a solitary ovule pendulous from apex .....TYPHACEAE

aa Perianth absent or represented by 'hypogynous setae' or 'scales' or 'lodicules'; flowers minute arranged in spikelets with scale-like bracts (glumes or lemmas)

b Flowers enclosed by a single bract (glume) without a bracteole; leaves usually with closed sheaths, stems mostly solid and usually more or less triangular in cross-section ..... CYPERACEAE

bb Flowers each enclosed by a bract (lemma) and a bracteole (palea), the spikelet usually having 2 empty bracts (glumes) below the flowers, leaves usually with open sheath; stems mostly with hollow internodes and usually circular in crosssection ..... GRAMINEAE

AA Ovary inferior .... HYDROCHARITACEAE

Typhaceae

Tall, erect perennial herbs with simple, jointless stems, 2-ranked linear, sheathing leaves, and thick, branching rootstocks. Inflorescence a dense, rigid spike, 2 to 4 dm. long, usually breaking out of a spathe. Flowers numerous, imperfect, reduced, and naked, the lower pistillate and the upper staminate. Fruit minute, on a long stalk, with a single genus with about twelve species.

Typha

Typha australis Schum. and Thonn.

Leaves linear or strap-shaped. $\frac{1}{4}$ — $\frac{1}{2}$ in. broad. Male and female portions of spike subequal, contiguous to 1 in. distant. Male bracteoles variously shaped, entire or 2-3 forked. Female bracteoles as long as, or slightly longer than hairs and lanceolate - spathulate, sometimes fusiform-clavate, acute or acuminate.

Potamogetonaceae

Fresh- or salt-water, submersed aquatic plants. often with creeping rootstocks. Leaves alternate or rarely, opposite, on erect, jointed stems, or basal, simple, with a sheath or stipulate. Flowers perfect or imperfect, in spikes, cymose clusters, or solitary, often borne in a spathe. Perianth wanting, or of 4 to 6 small, herbaceous or membranous, separate or fused segments; stamens 1 to 6, distinct or rarely fused; ovary superior; fruit 1-seeded, indehiscent; seeds without endosperm.

Potamogeton javanicus Hassk.

Submerged plant; stems slender, branched. Submerged leaves narrow-linear, 2-3 in. long; floating leaves lanceolate, $\frac{1}{2}$ in. or more, petioled; lower stipules connate, upper free. Peduncle axillary; spikes $\frac{1}{4}$ - $\frac{3}{4}$ in. long. Fruit 2-keeled.

Hydrocharitceae

Dioecious or, ralely, monoecious or polygamous, aquatic herbs, mostly with clustered leaves at nodes of rhizomes or a few with leafy

stems. Flowers regular, sessile or on scapelike peduncles in a spathe; calyx usually of 3 sepals or lobes; corolla of 3 petals or wanting. In pistillate flowers the perianth fused into a tube end fused with the ovary of the compound pistil. Staminate flowers with 3 to 21 distinct or fused stamens. Pistillate flowers with 3 to 12 stigmas; ovary inferior ripening under water into a few - or many seeded, indehiscent fruit.

A Leaves broadly cordate, spathe winged ..... **Ottelia**

AA Leaves oblanceolate, spathe long toothed .... **Boottia**

Ottelia

Ottelia ulvaefolia Buch.

Leaves alternate at both ends, 7-nerved, 1 ½ in. broad. Spathe winged, obtusely 6-angled; ; inner perianth lobes yellow.

Boottia

Boottia scabra Benth. & Hook. F.

Leaves submerged, thin, oblanceolate, 1 ½ — 2 ft. long, 2 ½ in. wide; petiole 1 ft. long, expanded at the base into an amplexicaul base. Spathe 3½ in. long, unisexual, rugose, toothed. Petals yellow or cream coloured.

Gramineae

Plants with fibrous roots, nodose stems usually with hollow internodes, and narrow, parallel veined, 2-ranked leaves composed of sheath and blade. The sheath is wrapped around the stem with its margin overlapping but usually free. At the upper end of the sheath where it is jointed with the blade usually occurs a membranous or hair fringe, the ligule.

Flowers perfect or imperfect, arranged in 2-ranked spikelets which are clustered in panicles, racemes or spikes. Spikelets with a shorten axis on which are attached a few to many bracts, the glumes, the 2lower of which, the empty glumes are without flowers in their axil

the succeeding ones; the lemmas; or flowering glumes each bears a solitary axillary flower and palea on a short stalk. The midrib of the glumes may project into a long bristle or awn beyond the body of the glume. In some forms the upper or lower lemmas may be reduced or sterile.

Each perfect flower consists of 3 stamens, with filaments attached apparently at the middle of the 2-celled anthers, and a solitary pistil, with 1-celled, 1-ovuled ovary and, usually, 2 styles with plumose stigmas. Fruit a grain or caryopsis, often inclosed in, or surrounded by, the glume and palea. Embryo small along one side of the copious starchy endosperm.

A Spikes 2 or several together

a glumes awned ..... **Echinochloa**

aa glumes awnless ..... **Vossia**

AA Spikes solitary, terminal

b bristles persistent on pedicel ..... **Setaria**

bb bristles deciduous ..... **Pennisetum**

AAA Panicle

c tall perennial grasses with large hairy panicles, deciduous ..... **Phragmites**

cc not so ..... **Panicum**

Ehinochloa

Echinochloa Crus Pavonis Schult.

Annual up to 5 ft. high with copious plump root fibres. Stems erect, up to $\frac{1}{4}$ in. thick, spongy below. Leaves 5 — 15 in. long, and up to 1 $\frac{1}{4}$ in. wide, from a narrow base, and tapering to a fine point. Inflorescence erect, large, 4—12 in. long, lanceshaped, rather feathery;

lower branches up to 4 in. long, dense. Spikelets nearly $\frac{1}{8}$ in. long, narrow, strongly ribbed, glumes shortly awned ($\frac{1}{8}$ in.) from the entire acute tip, minutely hairly, purplish or dark in colour.

E. pyramidalis Hitchcock & Chase

Perennial, reed-like grass up to 15 ft. high. Stems ascending from a long thick abundantly rooting, often floating base. Leaves narrow, 1-2 ft. long by $\frac{1}{4}$ - 1 in. broad, flat, narrow at the base, long tapering to a point, the lower sheathing portion coarsely bearded. Inflorescence erect or somewhat nodding, up to over 1 ft. long, rather narrow, dense branches numerous, 1 - 6 in. long. Spikelets ovate, up to $\frac{1}{6}$ in. long, very crowded, often coloured blackish purple, awnless, but strongly tipped. Axis hairy with long silky hairs.

E. stagnina P. Beauv.

Stout perennial grass, rising to 6 ft. from long creeping and copiously rooting rhizomes; leaves narrow, long tapering to a fine point, up to $1\frac{1}{2}$ ft. long by 1 in. wide, very rough upwards. Inflorescence up to 10 in long, nodding, narrow and often open, branches dense. Spikelets up to $\frac{1}{4}$ in. long, plump, tapering at both ends, awns up to 1 in. long.

Vossia

Vossia cuspidata Griff. (Fig. 3)

A very large floating grass, perennial, one of the principal constituents of the Sudd, copiously rooting from enlarged nodes, aerial portion up to over 3 ft. high, racemes solitary or 2 - 6 on a common axis, 6 - 9 in. long, short, erect or slightly nodding, joints about $\frac{1}{3}$ in. long, curved, swollen, lower glume of sessile spikelets smooth with a chanelled, pointed tail up to 1 in. long; spikelets 2-flowered, awnless.

Setaria

Setaria aurea A. Braun.

Strong-growing erect grass about 3 ft. high, with slender stems from a short rhizome which is covered with the remains of old scales and sheaths. Leaves long, narrow, tapering $\frac{1}{2}$ - $1\frac{1}{2}$ in. by $\frac{1}{3}$ - $\frac{1}{8}$ in., usually flat. Inflorescence erect, straight, up to 1 ft. long. Bristles more

Fig. 3
Vossia cuspidata *Griff.*

than one at the base of each spikelet, and exceeding spikelet by $\frac{1}{12}$ in., yellowish to bright orange or reddish in colour. Spikelets clustered, $\frac{1}{8}$ in. long.

Pennisetum

Pennisetum purpureum Schum.

Tall perennial grass up to 20 ft. high, spreading by creeping underground stems; spikelets arranged round a densely hairy central axis forming a compact, erect, bristly cylindrical spike which becomes bent at maturity. Spike up to 1 ft. long. Anther tip minutely hairy.

Phragmites (Fig.4)

Phragmties communis Trin.

Tall perennial grass, erect, 4 – 12 ft. high or taller, many jointed. Inflorescence large, tasel-like, brownish, branches of panicle very membranous, fine. Spikelets $\frac{1}{2}$ - $\frac{3}{4}$ in, lo with fine white silky hairs, glumes narrow, pointed.

Panicum

Panicum aphanoneurum Stapf.

Perennial, densely tufted, 4-ft. high, stems stout, reed-like. Leaves $\frac{1}{2}$ to $1\frac{1}{2}$ ft. by $\frac{1}{6}$ – $\frac{1}{2}$ in.,narrow fr an equally wide base, tapering. Panicle rather loose, $\frac{1}{2}$ to over ft. by 2 – 5 in., irregularly branched at the base. Spikelets widely gapping; tinged with purple, upper glume faintly 5 - nerved.

Cyperaceae

Plants with the general appearance of grasses, with fibrous roots and mostly solid stems, often from creeping rootstocks. Leaves mostly

Fig. 4

Morphological Features of Phragmites communis *Trin;*

linear, parallel-veined, basal or alternate on the stem, 3 - ranked, with closed sheath. Flowers in the axils of scales (glumes) in spikelets, reduced, naked or subtended by bristles or scales, perfect or imperfect. Stamens 3, with anthers attached basally. Ovary 1 - celled, 1 - ovuled, with 2- or 3-cleft style. Fruit an achene, flattened, lenticular or 3-angular. Seed with small embryo and large, starchy endosperm.

A Spikes in many-rayed simple umbels ..... **Pycreus**

AA Spikelets several in a terminal crowded head ..... **Cyperus**

Pycreus

Pycreus Mundtii Nees.

Stems 8-24 in. long, decumbent and rooting at base and clothed with leaf-sheaths up to $\frac{3}{4}$ of its its length. Leaves 4-10 in. long. or 1 spike only, bearing 3-8 ebracteolate spikelets; bracts 4 to many, overtopping the umbel; spikelets containing 12 16 fertile glumes, brown; nuts biconvex, dotted.

Cyperus

Cyperus nudicaulis Poir.

Floating herb; rhizome long, stems tufted, 12-30 in. long. Leaves reduced to pale-brown leaf sheaths. Head of 1-12 sessile spikelets; bracts 1 - 3, the lowest suberect, continuing the stem, shorter than head; spikelets $\frac{1}{2}$ - 1 in. long, flattened, 30-70 flowered, pale or reddish; glumes 3-nerved; stamens 3; style long, branches short; nut $\frac{2}{3}$ length of glume; flattened base corky, thickened.

C. **dichroostachyus** Hochst.

Glabrous herb; rhizome 4-8 in. long; stems distant, 18-36 in. long, sharply 3-angled at top. Leaves $\frac{1}{2}$ - $\frac{3}{4}$ length of stem, up to $\frac{1}{2}$ in. broad. Umbel lateral, compound, 2-5 in. diameter; bracts 3-4, up to 8 in. long, lowest in cotinuation of stem. Spikes of 3-5 spikelets, digitate, numerous, spikelets white, brown spotted, 6 - 14 flowered, glumes 1-nerved obtuse; stamens 2; style very short, nut $\frac{3}{4}$ length of glume, yellow brown.

C. **sphaerospermus** Schrad.

glabrous herb; rhizome woody, 2 in. long; stems 6-14 in. long, more or less sharply 3-angled at top. Leaves from ½ the length to more than length of stems. Umbel simple or compound, 1–5 in. diameter; bracts 1 in.; spikes of 3-8 digitate spikelets, straw-coloured or rich brown; spikelets ½ in. long, compressed, 10 - 30 flowered; stamens 3; style short, branches longer than the minute nut.

C. **Papyrus** Linn. var. **Antiquorum** C.B. Clarke. (Fig.5)

Plant up to 15 ft. high, rhizome woody; stems smooth with basal sheaths only. Leaves up to 1 in. by ⅛ in. on barren shoots. Umbels compound, up to 3 ft. diameter; primary rays up 30, up to 1 ft. long; bracts up to 7 in. long, reddish; spikelets numerous sessile, ovate, ¼ - ⅓ in. long, compressed; bracts of secondary umbel 3. up to 2½ in. long. Spikes about 1 in. by ½ in. with 12–30 spreading spikelets; spikelets ⅓ in. long, brown; glumes ovate-oblong with a green median line; rachilla wings yellow deciduous late; stamens 3; style length of nut; branches rather short, nut ½ - ⅜ length of glume, black.

C. **cephalotes** Vahl.

Stolons slender; stem 6-10 in. long, 3-angled. Leaves longer or shorter than stem. Head globose, ½ diameter; bracts 3 - 4; spikelets numerous, sessile, ovate, ¼ - ⅓ in. long, compressed, 20-30 flowered; rachilla not winged; glumes cuspidate, imbricate, red brown; stamens 2-3; nut oblong, narrowed into a long beak, style jointed on beak of nut, slender, entire or 2-3 toothed.

Araceae

Stout plants with alternate, simple or compound, fleshy leaves. Flowers reduced, often without perianth, imperfect or perfect, crowded on a spadix which in most genera is surrounded by a large bract, the spathe. Fruit a berry or utricle.

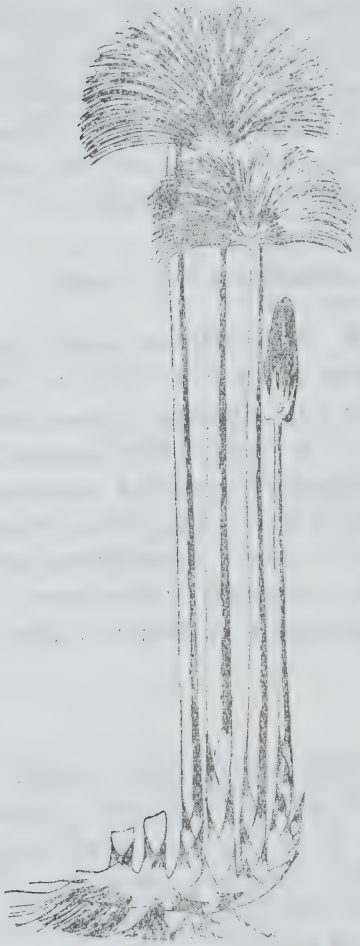

Fig. 5

Morpholegicul Fcatures of Cyperus papyrus *Linn.*

Pistia

Pistia Stratiotes Linn. (Fig. 6)

Gregarious floating, stemless, monoecious herb, with tufted root fibres. Leaves sessile in a rosette forming a cup; nerves radiating from base. Spathe small with spadix adnate to back of its short tube. Male inflorescence a whorl of 2-8 connate anthers near top of spadix. Female flower of a single ovary, apparently arising from back of spathe.

Lemnaceae

Plants minute, free floating or submersed, with undifferentiated, flattened or globular plant body (frond) without definite leaf or stem, single, or aggregated in small colonies. Frond with or without roots, propagating readily by buds bursting through a flap of the vegetative pouches. Flowers borne in a reproductive pouch on the margin or upper surface of the frond; imperfect, much reduced, naked, appearing usually after a period of hot weather. Fruit a utricle.

Lemna

Lemna sp. L. (Fig. 7)

Plants minute, free floating without definite leaf or stem. Fronds flattened, 1-5 nerved proliferating from 2 vegetative pouches on the margin near the base usually bearing a single root Flowers 3, borne in the flowering pouch, 2 staminate, each composed of 1 stamen, and the other pistillate, composed of a single naked pistil. Ovary 1-celled, with 1-several ovules. Fruit usually 1 seed.

Commelinaceae

Annual or perennial herbs with knotty, stem. Leaves alternate, entire, vaginate or clasping, the blades ovate-lanceolate or linear, Flowers bisexual, with 3 green sepals, sometimes slightly connate below, and with 3 fugitive petals, which are either free or united into a tube. Stamens 6 (rarely 3), often some reduced to staminodes; filaments

Fig. 6 A) : *A natural stand where* Pistia stratiotes *Linn. appears floating near* Vossia *plants.*

Fig. 6 B) : *Morphological Features of* Pistia stratiotes *Linn.*

Fig. 7 : Lemna sp. *L.*

often hairy. Ovary superior, 2-3-celled, with few or many ovules; style and stigma solitary, the latter sometimes obscurely 2-3 lobed. Fruit capsule.

Commelina

Commelina nudiflora Linn.

Marsh herb, stems decumbent, 1-2 ft. long. Leaves alternate 1-3 in. long, lanceolate; sheaths 1-2 in long. Inflorescence of 2 racemes enclosed in a folded ovate-lanceolate, $\frac{1}{2}$ – 2 in. long spathe; flowers 1-3 in the lower and 3-8 in upper raceme; sepals 3; petals 3, 2 with long claws, blue; stamens 2-3 perfect, 2-3 sterile; seeds 5-reticulated.

KEY TO THE FAMILIES OF DICOTYLEDONS

A Gynoecium (pistil) composed of 2 or more separate carpels or the carpels may be nearly quite separate; styles free and stigmas free; the free carpels may be immersed in the expanded torus. Petals free from each other, sometimes modified; aquatic plents with floating leaves and showy flowers ..... NYMPHAEACEAE

AA Gynoecium (pistil) composed of 1 carpel or of 2 or more united carpels with free or united styles, or if carpels free below then the styles or stigmas united

a Ovules 2 or more attached to ovary wall;

b Ovary superior; petals present free from each other. Ovary of 1 carpel with only 1 placenta; fruit a legume .. .. LEGUMINOSAE

bb Ovary inferior. Petals present more or less united

c Flowers hermaphrodite leaves oppusite or verticillate, entire with interpetiolar or intrapetiolar stipules, trees or shrubs sometimes climbing but without tendrils .... RUBIACEAE

cc Flowers unisexual, leaves alternate often lobed or digitately divided, mostly climbing or postrate by tendrils . . CUCURBITACEAE

aa Ovules 1 or more, if more than 1 then attached to the central axis or the base or apex of ovary

b Ovary superior

c Petals present free from each other

d Stamens as many as and opposite petals. Flowers in leafopposed inflorescences herbaceous or woody plants, often climbing with tendrils leaves simple often lobed

or divided or digitately compound, fruit baccate . . . . . AMPELIDACEAE

dd Stamens as many as and alternate with the petals, or more or less united into a tube, anthers 1-locular, herbs or under shrubs often with stellate hairs MALVACEAE

cc Petals present more or less united

d Ovary 1-locular; flowers strongly zygomorphic, the corolla spurred, herbs usually aquatic, the leaves often bearing bladders; stamens 2; ovary with numerous ovules on free basal placenta . LENTIBULARIACEAE

dd Ovary of 2- or more-locular

e Stamens fewer than corolla lobes (2-4)

f Ovary with few(1-4) oveles in each locule .VERBENACEAE

ff Ovary with numerous ovules (more than 4) in each locule . . . . . SCROPHULARIACEAE

ee Stamens as many as corolla-lobes

f Corolla induplicate; ovary usually with 4 basal ovules, often twining .. .. CONVOLVULACEAE

ff Corolla contorted

g Flowers with a corona, stamens ofton united and with the pollen agglutinised into masses; often containing latex .. .. ASCLIPIADACEAE

gg No corona, latex may be present .. APOCYNACEAE

ccc Petals absent

d Plants submerged. Leaves verticillate deeply divided, flowers unisexual, solitary at the nodes, sessile CERATOPHYLLACEAE

dd Plants not submerged

e Ovary trilocular, flowers unisexual EUPHORBIACEAE

ee Ovary unilocular, flowers hermaphrodite POLYGONACEA

bb Ovary inferior

c Petals; present, free from each other

d Ovary with numerous ovulesl in each loculus, stamens as many or twice as many as the petals; flowers not in umbels . . . . . ONAGRACEAE

dd Ovary with 1 ovule in each loculus, flowers in umbels, fruit separating into 2 indehiscent cocci; leaves usually much divided with sheathing bases. . UMBELLIFERAE

cc Petals present more or less united; Stamens with the anthers united into a tube surrounding the style, ovule erect from the base of the ovary; corolla of the outer (ray) flowers often differing from that of the inner flowers the flowers being arranged in bracteate heads (capitula) COMPOSITAE

Polygonaceae

Mostly herbs, raely shrubs. Leaves possess peculiar sheathing stipules or ochreae clasping the stem above the leaf base. Flowers perfect, or polygamous-monoecious or dioecious, have 6 perianth leaves in 2 whorls, or 5 arranged according to the $^2/_5$ phyllotaxy. Ovary 1 locule with 1 erect orthotropous ovule. Fruit triangular nut with persistent perianth.

Polygonum

Polygonum tomentosum Willd. (Fig. 8)

Tall aquatic herb, more fulvous than **P. lanigerum**; stamens usually 7; bracts truncate, ciliate, otherwise as **P. lanigerum**.

P. lanigerum R. Br.

Hairy aquatic herb, 4-5 ft. high. Leaves lanceolate, up to 9 in. long; ochreae long, membranous, ciliate. Racemes dense, 1-3 in. long; bracts orbicular; perianth $\frac{1}{6}$ in. long; stamens 6; styles 2; fruit lenticular, black.

P. glabrum willd.

Glabrous marsh herb, 3-4 ft. high. Leaves oblong-lanceolate, up to 8 in. long; ochreae large, membranous. Spikes dense, 2 in. long; perianth pink; stamens 6-8; styles 2; nut lenticular, orbicular.

Nymphaeaceae

Aquatic herbs with peltate or cordate leaves arising from a submerged prostrate rhizome. Flowers solitary, large and showy, often sweet-scented. Sepals 4-6, free or adherent to the receptacle. Petals numerous, free, imbricate, sometimes gradually passing into stamens. Stamens numerous. Carpels 8 or more, free and immersed in the receptacle or less united into an ovary of as many loculi, inferior or semi-inferior; ovules numerous. Receptacle large fleshy surrounding the ovaries or ovary and with the petals and stamens inserted on its side. Fruit multilocular, indehiscent, fleshy

Fig. 8 A) : *A stand of "Sudd" vegetation where* **Polygonum** lanigerum *R.Br. is represented.*

Fig. 8 B) : *Morphological Features of* Polygonum lanigerum *R.Br.*

Nymphaea

Nymphaea lotus L. (Fig.9)

Leaves sharply toothed, often hairy beneath, with many strong nerves. Flowers white, sometimes bluish or purple-tinged or yellowish. Sepals pure-green on the back, white at the base with white prominent veins. Anther connective blunt and very shortly produced.

N. micrantha Guillem. & Perrott.

Leaves entire or slightly undulate, glabrous or nearly so beneath and marked with violet-black dots bearing a cluster of bulbils at the top of the petiole, 4—6 in. long. $3\frac{1}{4}$ — $4\frac{1}{2}$ in. broad. Flowers white to bluish, about 4 — $4\frac{3}{4}$ in. in diameter when spread out. Sepals marked with violet dots. anther-connective shortly produced, conical.

N. caerula Savigny = **N. nubica Lehm.**

Leaves entire or slightly undulate at the base. orbicular or ovate-orbicular, narrowly peltate up to 16 in. broad, green beneath with small dark-purple spots, purplish all round near the margin, not beariug a cluster of bulbils. Flowers light-blue above, dull white below. Sepals thickly marked with black lines; anther connective long-produced, slender, pale-blue.

Ceratophyllaeeae

Submerged aquatic herbs with leafy branches. Leaves verticillate, variously divided with thread-like or linear segments. Flowers monoecious, solitary, sessile, males and females at separate nodes. Calyx thinly herbaceous, many parted into narrow subvalvate segments often dentate or lacerate at the apex. Petals absent. Male flowers : stamens 10—12, crowded on a flat torus connective produced beyond the loculi, thick and often coloured. Female flowers: ovary sessile, ovoid, 1-locular, ovule 1. Fruit a nut, ovoid or ellipsoid

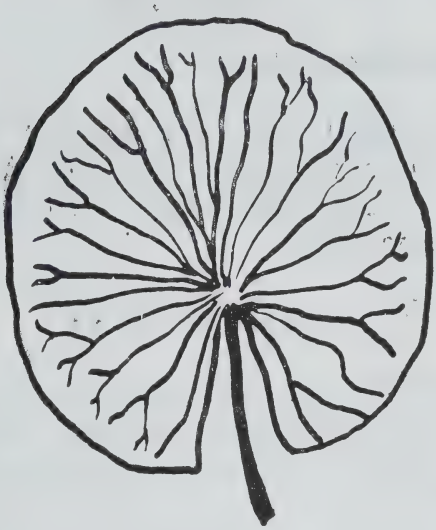

Fig. 9 Nymphaea micrantha *Guillem. and Perrott.*

Fig. 10 Ceratophyllum demersum *Linn.*

Ceratophyllum

Ceratophyllum demersum Linn. (Fig. 10)

Glabrous perennial herb, with elongated branches. Leaves in worls of 5-12, more or less deeply divided. Flowers small. Calyx-segment oblong. Fruit about $\frac{1}{4}$ in. long, broadly ellipsoid, strongly warted and crowned with a long beak.

Leguminosae

Stems commonly erect ; many climbers. Some climb by leaf ten drils, some by stem tendrils, some by hooks and some by twining. Creeping stems, rooting at the nodes, also occur. Thorns which are modified branches are common. The stems of the erect tropical species often branch so that the branches run parallel and erect, and bear crowns of leaves at the top. Leaves usually alternate, stipulate and nearly always compound. Many have very small leaves or scaly ones. The stipules vary much in size. Inflorescences apparently always racemose, but with variety ; simple raceme very common, also panicle and spike. The flowers are actinomorphic or zygomorphic, hermaphrodite or polygamous. Receptacle usually convex or flat, so that at most the flower is slightly perigynous. Calyx usually 5-merous, the odd sepal anterior, more or less united. Corolla polypetalous, alternate with sepals; valvate or ascending imbricate or descending. In most cases it is irregular to a high degree having a large posterior petal (vexillum or standard), two lateral (alae or wings), and 2 anterior more or less jointed to form a carina or keel. Stamens typically 10, free or united into a tube ; in the latter case the tenth stamen (the posterior one) often remains free, so as to leave a slit in the tube, only covered loosely by this stamen. Gynoecium typically of 1 superior carpel with its ventral side directly posterior, long style and terminal stigma. There are 2 rows of ovules, alternating with one another so as to stand in one vertical rank. Fruit typically a legume or pod opening by both sutures. The pod may be constricted between the seeds, forming a lomentum. Pods are sometimes inflated.

A Flowers regular, very small, in spikes or heads ... ... **Mimosa**

AA Flowers irregular, papilionaceous

a pod not jointed

b Leaflets usually more than 1 in. long ... ... **Phaseolus**

bb Leaflets usually less than 1 in. long ... ... **Vigna**

aa Pod jointed, constricted between the seeds and sometimes breaking into 1 - seeded portions ... ... **Aeschynomene**

Mimosa

Mimosa asperta Linn

straggling, prickly shruub. Leaves bipinnate, sensitive, pinnae 7 - 16 pairs; leaflets 25-40 jugate. Flower heads globose, pinkish, on about 1 in. long axillary peduncles. Pod very hairy, compressed, linear-oblong 1 in. long.

Phaseolus

Phaseolus adenanthus G.F.W. Mey.

Wide-climbing nearly glabrous perennial herb with a tuberous root. Leaflets 3, broadly ovate, $2\frac{1}{2}$ - 5 in. long, glabrous beneath except on the nerves, the lateral leaflets unequal sided. Flowers pink and white turning yellow, glabrous, about 1 in. long in rather stout 6-12- flowered axillary racemes. Pod linear, 4-$5\frac{1}{2}$ in. long, nearly flat with thicker margins, 10- or more- seedad,

Vigna

Vigna nilotica Hook. f.

Herbaceous twiner, leaflets 3, ovate lanceolate, flowers yellow, about $\frac{3}{4}$ in. long, in close racemes on peduncles 3-5 in. long. Pod 2-3 in. long and $\frac{1}{4}$ in. broad, slightly curved, pendulous.

Aeschynomene

Aeschynomene elaphroxylon = **Herminiera elephroxylon** Gullem. & Perrott. (Fig. 11)

Tree or shrub up to 20 ft. high, short, swollen, quickly tapered (often almost conical), armed with prickles, bark green, smooth;

Fig. 11 Aeschynomene = Herminiera elaphroxylon *Guillem. and Perrot.*

Fig. 12 *Morphological Features of* Cissus ibuensis *Hook. f.*

branchlets densely hispid, armed with up-curved brown prickles up to $\frac{1}{3}$ in. long. Leaves paripinnate, 2-4 in. long, the rachis frequently prickly; leaflets in 10–20 pairs, oblong, emarginate and mucronate at the apex, usually $\frac{1}{8}$ - $\frac{2}{3}$ in. long. Flowers handsome, orange yellow, in short 2-3 flowered axillary racemes. Corolla more than 1 – $\frac{1}{2}$ in long Pod bristly.

A. cristata Vatke.

Shrub or undershrub up to 20 ft. high; stems branches as well as the penduncles at first setose, becoming glabrous. Leaflets about 20 pairs. oblong lanceolate, about $^2/_5$ in. long. Flowers axillary; Pod about 4 in. long, glabrous.

A. ptundii Taub.

Shrub up to 9 ft. high; stems, etc., golden - tomentcse, not prickly. Leaflets numerous, serrulate, about 1 in. long. Flowers few in racemes. Pod up to $\frac{3}{4}$ in. broad. densely pilose, breaking up into narrowly oblong segments.

Euphorbiaceae

Trees, shrubs or herbs, occasionally with milky juice. Leaves alternate or rarely opposite usually with stipules, simple or digitately compound, sometimes reduced. Flowers unisexual, mostly monoecious. Sepals imbricate or valvate, or in very specialised inflorescences much reduced or absent. Petals absent or rarely present and sometimes 1– numerous, free or variously connate: anthers 2–(3-4) - locular, erect or inflexed in bud opening lengthwise, or rarely by pores. Rudimentary ovary often present in the male flowers. Ovary usually 3 - locular, styles free or united at the base, solitary or paired, pendulous from the inner angle of the loculi. Fruit a capsule or drupe, seeds often with a conspicuous caruncle.

Euphorbia

Euphorbia abssinica J. F. Gmel.

Spiny leafless tree, branches 3 – 8 angled, straight, irregularly costricted with wing-like angles up to 1 in. broad. Spines in pairs up to 1 in. long, on suborbicular shields close together but not connected. Cymes crowded at the top of branchlets. Carpels at first green becomin

deep-crimson, streaked with white, with a distinct fleshy 3-lobed involucre at its base, and exerted on a stout pedicel, 3-angled, glabrous.

Ampelidaceae

Climbing shrubs or small trees or herbs from a perennial rootstock; stems rodose or jointed, often with watery juice. Leaves usually wfth stipules, alternate or the lower sometimes opposite, simple or digitately compound or bipinnate, often pellucid-punctate. Flowers hermaphrodite or unisexexual, actinomorphic, small, in leaf-opposed spikes or raecmes or cymes or panicles, peduncles often with tendrils. Calyx small, entire or 4-5 toothed or lobed. Petals 4-5, free or united, valvate, falling early. Disc present. intrastaminal, usually very distinct. Stamens 4-5, opposite the petals, inserted at the base of the disc, anthers free or conrate, 2- locular. Ovary 2-6-loular, loculi 1 - 2 ovuled, style short; stigma capitate or discoid. Fruit a berry, often watery, 1-6 locular.

Cissus

Cissus ibuensis Hook.f. (Fig. 12)

Wide climber, stems often rather deeply striate, slightly pupescent to glabrous, branches as well as the leaves somentimes slightly succulent, Leaves 3-foliate, leaflets oblong-elliptic to ovate at the apex rounded at the base, $1\frac{1}{8}$- 3 in. long, $\frac{3}{4}$-$1\frac{1}{4}$- in. broad glabrous on both surfaces when maturc except sometimes on the nerves beneath. Flowers greenish, in copiously compound cymes $1\frac{1}{2}$-2 in. broad for peduncles 4-6 in. long. Fruit about $\frac{1}{2}$ in. in diameter, glabrous.

Malvaceae

Herbs, shrubs or trees with alternate stipulate leaves. Flowers solitary or in cymes, hermaphrodite, regular usually 5 merous. Epicalyx often present. Calyx five, free or united, valvate sepals. Corolla 5, the branching of the inner whorl all united below into a tube which is joined to the petals. Anther 1- lobed, pollen grains spiny. Ovary 1-numerous superior carpels, frequently five united, multilocular with axile placenta; ovules 1-numerous in each locule, frnit usnally capsule or schizocarp.

A Plants armed. . Hibiscus sp. AA Plants unarmed **Triumphetta sp.**

Hibiscus

Hibiscus diversifolius Jacq. (Fig. 13)

Tall herb or undershrub, branches as well as the petioles, a ne with hard conical prickles. Leaves long-petiolate, cordate at the base, orbicular, angular 3-5-lobed, irrugularly toothed ; upper leaves elliptic or lanceolate. Flowers yellow with a red purple centre. large, in a terminal cluster. Capsule acute at the apex, very hispid, ultimately smooth ; seeds smooth.

Triumphetta rhomboides Jacq. (Fig,14)

Weedly herb or undershrub, variable in habit. Leaves variable irregularly serrate. Flowers yellow, small in spicate inflorescences; fruit 5/1 in. in diameter, tomentose between the prickles.

Onagraceae

Herbs or rarely shrubs, sometimes aquatic. Leaves opposite or alternate ; stipules usually absent or deciduous. Flowers hermaphrodite usually actinomorphic, often solitary. Calyx-lobes 4-5, va'vate. Petals 4-5, free, contorted or imbricate, rarely absent. Stamens as many as or twice as many as the calyx-lobes. Ovary inferior or semi-inferior, 2-6-locular ; ovules 1-many in each loculus. Fruit a capsule or nut ; seeds numerous or solitary.

A Seeds indefinite .. .. **Jussiaea**

AA Seed solitary .. .. **Trapa**

Jussiaea

Jussiaea diffusa Forsk. (Fig. 15)

Creeping or floating aquatic herb, rooting at the nodes and frequently with spindle-shaped pale-pinkish hairy floats. Leaves alternate, lanceolate, narrowed into the petiole, up to 3 ¼ in. long and ⅓ in.

Fig. 13 *Morphological Features of* Hibiscus diversifolius *acq.*

Fig. 14. *Morphological Features of* Triumphetta rhomboides *Jacq.*

Fig. 15. *Jussiaca diffusa* Forsk

broad. Flowers brightly yellow, solitary, sessile, small. Sepals and petals 4. Capsule up to 2 in. long, the fibres of old capsules persistent, seeds smooth, rounded, free.

Trapa

Trapa bispinosa Roxb.

Floating herb ; stems ascending in water, giving off numerous pectinate roots. Leaves alternate, rhomboid-triangular, almost trunctate at the base, coarsely dentate, about 1 ¼ — 1 ½ in. long and broad strongly pinnately nerved and laxly tomentose beneath ; petiole of the lower leaves elongated, dilated towards the top, pilose. Flowers solitary, axillary. Fruit woody, 2-horned, when ripe sinking to the bottom of the water.

Umbelliferae

Aromatic herbs, mostly with hollow, jointed stems and alternate leaves, the petioles expanded or sheathing at the base. Flowers small, perfect, in simple or compound umbels or rarely heads. Calyx entire or 5-toothed, fused with the ovary ; petals and stamens 5, attached on a disc on the ovary ; pistil 2-celled, with 2 styles which are enlarged at the base into the stylopodium. Fruit 2 dry, seedlike carpels (mericarps), splitting when mature. Mericarps 1-seeded, with 5 longitudinal ridges (primary ribs) and sometimes 4 intermediate ribs. oil tubes or oil-secreting tissues in the pericarp.

Hydrocotyle

Hydrocotyle natans Cyr.

Robust creeping perennial herb, rooting at the nodes. Leaves suborbicular or subreniform, distincly lobed and slit at the base up to the central insertion of the long petiole, 1-2 ½ in. in diameter; pêtiole thick, erect, sometimes about 1 ft. long, pilose when young. Flowers in about 7-flowered umbels on peduncles up to 3 in. long. Fruit ⅛ in. broad, with weak primary ridges.

Apocynaceae

Trees, erect shrubs or climbers, or rarely perennial herbs, often with a milky juice. Leaves without stipules, opposite or verticillate, or rarely alternate, simple, entire. Flowers hermaphrodite, actinomorphic. Corolla-lobes usually contorted-imbricate. Anthers often sagittate, free or connivent round the stigma or rarely adherent to the latter, the connective often produced at the apex ; pollen granular. Disc usually present, annular or cupular or of separate glands. Ovary superior, 1-locular with 2 parietal placentas or 2-locular with the placentas adnate to the septum, or carpels 2 and connate only at the apex and base with a ventral placenta in each carpel, stigma thickened. Fruit entire and indehiscent, or of 2 separate carpels ; seeds often winged or appendaged with long silky hairs.

Carissa

Carissa edulis (Forsk.) Vahl.

Much-branched shrub, branchlets glabrous or thinly and softly pubescent, armed with axillary spines. Leaves ovate, acute at the apex, rounded or broadly cuneate at the base, $1\frac{1}{2}$-$3\frac{1}{4}$ in. long, 1-2 in. broad, glabrous or thinly pubescent on the midrib beneath. Flowers white and wine-red, fragrant, in shortly pedunculate cymes. Fruit purple to black, globose, about $^{3}/_{4}$ in. long, glabrous, edible.

Asclepiadaceae

Perennial herbs or climbing shruby plants, with simple, entire apposite exstipulate leaves. Latex present. Inflorescence cyme or raceme. Flowers hermaphrodite, actinomorphic, hypogynous, 5-merous. Calyx quincuncial, usually united sepals. Corolla rotate or campanulate, petals 5 united. Stamens and carpels usually united to form gynostegium. Stamens 5, and carpels 2 united, ovary 2-loculed, in each many ovules; Fruit follicles; seeds with hairs.

Oxystelma

Oxystelma bornouense R. Br.

Slender twiner. Leaves oblong-lanceolate, mucronate at the apex, rounded or truncate or cordate-hastate at the base, 1 ½ — 3 in. long, ½ — 1 ¼ in. broad, glabrous. Flowers white with deep purpule-stained centre, 1 - 1 ¼ in. in diameter, in 2-4-flowered cymes. Fruit q ellipsoid, about 2 in. long, inflated, glabrous.

Convolvulaceae

Herbs, shrubs or climbers. Latex often present. Leaves alternate usually stalked, rarely stipulate. Inflorescence dichasium. Flowers hermaphrodite, regular, hypogynous, usually 5-merous. Calyx 5, frre rarely united sepals; corolla 5, united usually induplicate-valvate petals; stamens 5 alternate with petals and epipetalous on the base of petals; gynoecium usually 2 rarely 3-5 united superior carpels, ovary locular, usually 2 ovules on axile placenta in each locule. Fruit berry, nut or capsule.

A Calyx villous . . . . . **Merremia**

AA Calyx glabrous . . . . . **Ipomaea**

Merremia

Merremia pentaphylla Hallier f.

Slender twiner, hirsute with yellowish hairs. Leaves deeply 5-lobed, 2-4 in. long; petiole 2-4 in. Peduncle as long as leaf, few or many-flowered; corolla white or yellowish, 1 in. long, campanulate or funnel-shaped. Capsule ½ in. in diameter enclosed in persistent hairy sepals. Seeds brown, glabrous.

Ipomaea

Ipomaea aquatica Forsk. (Fig(. 19

Hollow-stemmed trailing and twining herb, also floating on water. Leaves cordate-ovate or hastate, 3-6 in. long, petioles. Peduncles 1-2

Fig. 16 Ipomaea aquatica *Forsk. twining on an aerial branch of* Phragmites. *Notice the large bell-shaped Flowers.*

in. long, 1-few-flowered; corolla bright purple, 2-2½ in. long, funnel-shaped, limb spreading, 2½ in. diameter; capsule globose, ⅓ in. diameter.

Ipomaea repens Lam.

Trailing perennial with hollow stem, growing on muddy banks. Leaves cordate, orbicular or reniform, 3-6 in. diameter; petiole 1-4 in. long, bearing a few to many flowered cyme; corolla red or purple, funnel-shaped, 2-3 in. long. Capsule globose; seeds size of a pea.

Ipomaea palmata Forsk. (Fig.17)

Twining herb. Leaves with 5 lanceolate segments, the 2 lower bilobed, 1-3 in. long; petiole same length, based by stipular, 7-8 partite leaves. Cymes axillary, lax, few to many-flowered; corolla red-purple, 1½ - 2 in. long, funnel-shaped. Capsule globose, under ½ in. diameter; seeds 4, white, hairy.

Ipomaea lilacina Blume.

Strong twiner. Leaves cordate-ovate, sometimes 3-lobed, 3-4 in, long, more or less, pubescent. Peduncle 2-5 in. long, many-flowered; corolla lilac-pink, 1½ - 2 in. long, funnel-shaped. Capsule globose; seeds hairy.

Verbenaceae

Herbs, shrubs, trees or laines. Leaves usually opposite exstipulate. Inflorescence raceme or cyme, often with an involucre of bracts. Flowers bracteate, bracteolate, usually hermaphrodite, zygomorphic, usually 5-merous and hypogynous. Calyx (5) or (4-8) united petals, usually narrow-curved tube, rarely campanulate, ofted 2-lipped. Stamens 4 didynamous alternate with corolla lobes and epipétalous. Gynoecium usually 2, rarely 4 or 5 united superior carpels; ovary 4, 8 or 10 locules, in each 1 ovule on axile placenta. Style single, terminal, stigma usually lobed. Fruit generally a drupe, more rarely a capsule or schizocarp.

Fig. 17 *Morphological Features of* Ipomaea palmata *Forsk.*

Clerodendron

Clerodendron near **C. nerifolium** wall.

Shrub, about 5 ft. high, branches 5-angled, sulcate. Leaves ternate below, alternate above, lanceolate to ovate-elliptic, larger ones sometimes obsoletely and coarsely serrate. Flowers axillary in simple and compound cymes, forming terminal panicles; calyx $\frac{1}{2}$ in. long, accrescent and broadly campanulate in fruit, 5-toothed, corolla white, tube 1 in. long, slender, lobes 5; stamens 4, 1 in. long, didynamous, exserted; style 1 1/2 in. long, bifid; ovary 4-celled, ovules 4. Drupe black.

Scrophulariaceae

Herbs or undershrubs. Inflorescence raceme or cyme. Flowers hermaphrodite, zygomorphic or actinomorphic. Calyx (5) ; Corolla (5) medianly zygomorphic, often 2-lipped. Stamens 4, sometimes 2 didynamous, epipetalous. Gynoecium 2 united superior carpels, medianly placed, 2-loculed, with axile placentas, ovules numerous, style simple or bilobed. Fruit capsule or berry.

Rhamphicarpa

Rhamphicarpa fistulosa Benth.

Erect branched herb, usually about 1 ft. high. Leaves pinnatisect or bipinnatisect, up to 3 in. long, campanulate, 5-fid, $\frac{1}{4}$ in. long; corolla white, tube slender, 1-2 in. long; limb spreading, $\frac{1}{2}$—$\frac{1}{4}$ in. diameter, 5-lobed. Capsule ovoid, compressed, almost 2-winged, $\frac{1}{3}$—$\frac{1}{2}$ in. long.

Lentibulariaceae

Mostly delicate herbs with racemose or solitary, perfect flowers. Calyx and corolla 2-lipped; stamens 2; pistil with a 1-celled, superior ovary with free-central plecenta. Fruit a capsule, with a few or many seeds without endosperm.

Utricularia

Utricularia Thonningii Schumach

Floating aquatic herb, about 1 ft. long. Stem slender bearing verticels of bladder-bearing pectinate-filiform leaves and scapes bearing near their base verticel of up to 6-spindle shaped floats and above -many flowers. Sepals 2, enlarged in fruit; corolla pinkish, 2-lipped and spurred; stamens 2

Rubiaceae

Trees, shrubs er herbs, with decussate stipulate entire or rarely toothed leaves. The stpiules exhibit great variety of forms. Inflorescence typically cymose; flowers usually hermaphrodite, regular epigynous, 4-5 sepals, often almost absent, usually open. Corolla 4-5 unitod valvate, convolute or imbricate petals. Stamens 4-6, alternate with petals and epipetalous. Gynoecium usually (2) united superior carpels, 2-loculed each with 1-many ovules. Style single, stigma capitate or lobed. Frui capsule, berry or schizocarp.

A Annuals ..... **Octodon** AA Shrubs or trees ..... **Morelia**

Octodon

Octodon filifolium Schum. & Thonn.

Erect annual, 1 – 2 ft. high. Leaves opposite, filiform up to 4 in. long: Flowers 10–20 together within the stipular sheath of the upper leaves and surrounded by numerous filiform bracts: calyx teeth 8, purple; corolla lobes 4, white. Fruit dicoccous.

Morelia

Morelia senegalensis A. Rich.

Large shrub to small tree. Leaves oval or oblong, 2-7 in. long. Flowers up to ½ in. long, white fragrant, clustered in axillary cymes. Fruit globose, ½ in, in diameter, green.

Cucurbitaceae

Climbing or prostrate usually annual, tendril - bearing herbs. Leaves alternate, roundish entire or lobed. Flowers diclinous. Calyx and corolla pentamerous and regular. Stamens (5) united in various ways. Gynoecium usually (3) united inferior carpels, ovary trilocular, with many ovules in each locule. on axile placentas. Fruit usually flesh, berry-like.

A Filaments all united into a column **Coccinia**

AA Filaments free or united at the base or in pairs

b Tendrils simple **Momordica**

bb Tendrils 2-3-branched **Luffa**

bbb Disc at base of style well-developed **Melothria**

Coccinia

Coccinia grandis (L.) J.O. Voiht. = **Cephalandra quinqueloba** Schrad.

Prostrate or climbing herb, tendrils simple. Leaves deeply 5-lobed, 3-5 in. broad, with glands at the base of nerves. Flowers dioecious. Male flower solitary or subcymose, stamens 3, anthers connate, twisted. Female flower solitary, white or yellow. Fruit green with white mottling, scarlet when ripe, ellipsoid.

Melothria

Melothria cordata (Thunb.) Cogn. = **Zehneria cordifolia** Schwfth

Graceful climber, sparsely pilose, tendrils glabrous. Leaves broadly triangular-cordate, obtuse at the apex, $1\frac{1}{4}$ — 2 in. long and broad, petiole $\frac{1}{3}$ — $1\frac{1}{4}$ in. long. Male flowers minutely racemose, peduncle up to $1\frac{1}{4}$ in. long, 15-30-flowered. Female peduncle $\frac{1}{2}$ in. long. Fuit globose, about $\frac{1}{4}$ in. in diameter.

Momordica

Momordica Schimperiana Naud. (Fig. 18)

Herbaceous climber, with a tuberous root. Leaves ovate-cordate at the base, dentate, 4-8 in. long. Flowers yellow, $1\frac{1}{4}$ in. in diameter. Fruit scarlet when ripe, the size of an egg, covered with soft bristles.

Luffa

Luffa cylindrica Linn. Fig. 19)

Annual semi-woody climber, tendrils forked. Leaves often deeply digitately lobed, about 7-nerved at the base, scabrid. the lobes denticulate. petiole pubescent. Flowers yellow. about 2 in. in diameter. Fruit mottled-green when young. brown when ripe. woody ellipsoidal, with a dehiscing cap, seeds smooth, with a narrow wing.

Compositae

Flowers small, clustered in a head on a receptacle surrounded by bracts forming an involucre. The surface of the receptacle may bear the flowers and small bracts (chaff) or it may be free of bracts, i.e. have a naked receptacle. The calyx is modified and reduced to awns, bristles or scales (the pappus). The corolla, composed of 5 fused petals may be tubular, as in the disc flowers, or strap-shaped (ligulate) in the marginal or ray flowers. Stamens 5, attached on the corolla and mostly united by their anthers into a tube. Pistil with 1-celled, 1-seeded inferior ovary ripening into an achene, which is often crowned by the pappus. Seeds without endosperm.

A Herbs

a Leaves alternate, erect herbs .. .. **Blumea**

aa Leaves alternate, semi-woody herbs .. .. **Melanthera**

Fig 18 Momordica Schimperiana *Naud.*

Fig. 19 Luffa cylindrica *L.*

AA Perennials

a Corolla of the disc florets not ligulate .... **Senecio**

aa Corolla of all the florets ligulate .. .. **Sonchus**

Blumea

Blumea aurita DC.

Pubescent erect herb, 3 ft. high. Leaves alternate; radical leaves obovate or elliptical, cauline some are lyrate-pinnatipartite, auricled, 4½ in. long. Heads in corymbose terminal panicles, heterogenous, female flower filiform, disc flower hermaphrodite or sterile.

Melanthera

Melanthera Brownei Schultz. Bip. (Fig. 20)

Scabrid semi-woody herb, 2-10 ft. high. Leaves opposite, deltoid-ovate, sometimes 3-lobed acuminate, dentate, 2-6 in. long. Capitulum heterogenous, yellow in lax terminal cymes, ray flowers female, ligulate, disc flowers hermaphrodite.

Senecio

Senecio picridifolius DC.

Perennial 1-2 ft. high. Leaves alternate, oval-oblong or ovate, auriculate, toothed, puberulous, 1½ — 4½ in. long. Capitulum homogenous, 1 or few together, on 3—6 in. long peduncles, involucral bracts 1-seriate.

Sonchus

Sonchus Bipontini Aschers.

Glabrous perennial, 2—4 ft. high. Leaves linear, denticulate, up to 6 in. long, auricled, sessile. Capitulum yellow, flowers about 20, in corymbose cymes, inner involucral bracts about 8, lineaer, ultimately reflexed.

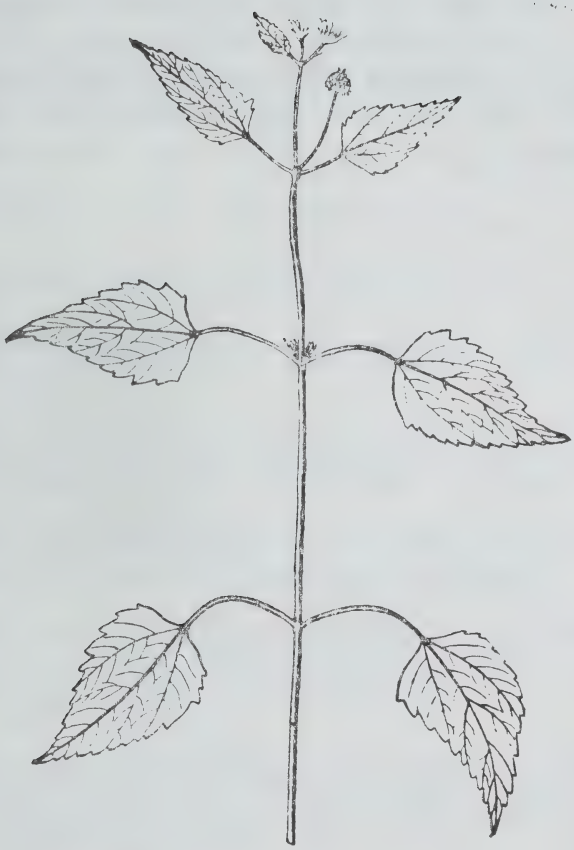

Fig. 20 Melanthera Brownei *Schultz. Bip.*

SUMMARY

The « Sudd" region in the Southern Sudan was visited by the writer in 1954, through an excursion arranged by the Ministry of Public Works. The writer got the opportunity to study the «Sudd" flora besides other ecological studies (Migahid, Abd-el-Rahman and Shafey (1959), which contribute to the distribution of the plants constituting the "Sudd". The data here quoted were obtained from personal observations as well as from references mentioned, and whenever possible drawings of the botanical material were made from living specimens. In addition, keys for the identification of the "Sudd" plants, were proposed.

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BINDING OF WATER IN PLANTS AND ITS RELATION TO DROUGHT RESISTANCE

By

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INTRODUCTION

It was as early as 1886 since Schroder investigated the capaclty for drought resistance of various plants and parts of plants. He found that seeds as well as many cryptogams readily endure disccation even to the extent of being reduced to an air-dry condition, The leaves of higher plants, on the other hand, perish before this state is reached.

Newton, Brown and Martin (1928) investigated the relation between drought tolerance, colloidal content, and bound water content in plant tissues. They found that the percentage bound water of the expressed sap of some plants was correlated directly with the known tolerance of these plants to drought conditions.

According to Maximov (1929), the principal means of overcoming the effects of soil dronght, are a reduction of the rate of water loos after the commencement of wilting, the accumulation of water reserves and an increase of the capacity of enduring drought without serious injury at the state of permanent wilting.

Tumanov (1927), in studying the influence of repeated wilting

on **Helianthus** plants, observed that the first permanent wilting makes the plant insensitive to further wilting.

Greathouse (1932), observed that by subjecting Soya bean to periodical wilting, the amount of bound water was increased. Binding of water has in every case been assigned to the accnmulation of hydrophilic colloids.

Migahid (1958), found that by growing **Kalanchoe aegyptiaca** in a relatively dry soil, its ability for drought resistance is increased.

The aim of the present study is to elucidate whether there really exists any relation between the bound water content of plant and its capacity for drought resistance.

In attempting to device means of protecting plants against the injurious effects of frost, previous workers, e.g. Newton, Brown and Martin (1916), Rosa (1921), paid attention to the so-called "hardening process", by which the plant becomes more resistant to frost. This was. brought about bykeeping the plant at a low temperature for a certain period In the present study, trails were made to harden plants against drought. by diminishing their tissue water content through subjecting them to repeated wilting. The effect of such treatment on the water-binding capacity of the plant was remakable.

MATERIAL AND METHODS

Vicia Faba L., **Colocynthis vulgaris** Schrad. and **Mesembryanthemum Forskhalei** Hochst. were grown from selected seeds in a misture of equal parts of sand and Nile silt in glazed pots; the moisture content being maintained at 50% of the total water-holding capacity. The pots were subjected to repeated wilting at two levels of soil moisture deficiency, namely 7% and 5% series. Thirty-six pots were used twelve for each plant in the two series The pots used were filled to within 2 cm. from the top with soil. Seeds were selected carefully for uniformity of size, shape and maturity, seeds-coat colour being often

as indicator of ripeness. In the case of **Colocynthis** and **Mesembryanthemum** all the seeds used were collected from the samc parent plant, while in the case of Vicia, the seeds were all of the type 81 obtained from the Breading Section of the Agricultural Department. Additional selection by weighing the individual seeds was made in the case of **Vicia** to increase further the degree of uniformity of the resulting seedlings.

Perforated glass tubes were used for irrigation and evaporation. and transpiration losses were balanced by weighing the individual pots daily and adding an amount of distilled water just sufficient to compensate the loss.

All seeds developed to well-grown plants in the case of **Vicia**, while less than one-half could develop in the cases of **Colocynthis** and **Mesembryanthemum**. The developed individuals were subjected to the first wilting (7% and 5% series), and those escaping the first wilting were subjected to the second wilting (also 7% and 5% series) in the following manner :

a) **First wilting** : when the plants reached a suitable stage of maturity, the soil was allowed to dry until the moisture had decreased to 7% of the total water-holding capacity in the first series and 5% in the second series. The moisture content of the soil was ascertained by weighing daily until the desired water content has been reached. Five days after the attainment of the desired water content, sufficient water was added to bring the moisture content to approximately 75% of the total water-holding capacity and at the end of two weeks, an estimation was made of the percentage of recovery, as well as the percentage of bound water. These criteria are considered to be an index of the relative capacity for drought resistance of the different species studied.

b) **Second wilting** : the plants which escaped the first wilting were subjected again to another wilting by allowing the soil to dry to the same levels as in the first wilting. Sufficient water was then

added in a manner similar to that followed after the first wilting. The percentage of plants that recovered, as well as the percentage of bound water, were estimated

Estimation of bound water

In the present study, the cryoscopic method was used for estimation of bound water in the expressed sap, while the differential concentration method was used for its determination in the pressed residue. The total bound water content of the original leaf tissue is the sum total of the bound water of its constituent parts : sap and residue, expressed as percentage af the total water content of the original leaf. This would necessitate a knowledge of the distribution of water between the expressed sap and the pressed residue. For more information about the methods of calcuculation, reference may be made to Migahid and Shafey (1956)

Results and Discussion

The effect of repeated wilting on **Vicia**, **Colocynthis** and **Mesembryanthemum** is smmarised in the following table :-

Bound Water Content and Percentage of Recovery From Wilting in Vicia Faba, Colocynthis vulgaris and Mesembryanthemum Forskhalei

Plant	First Wilting				Second Wilting			
	7% Series		5% Series		7% Series		5% Series	
	% of Recovery	% Total bound water	% of Recovery	% Total bound water	% of Recovery	% Total bound water	% of Recovery	% Total bound water
Vicia	0	0	0	0	0	0	0	0
Colocynthis	20	20.35	0	0	20	26.67	0	0
Mesemb.	80	21.77	60	28.60	70	28.23	60	40 53

Vicia did not show any sings of drought resistance under the conditions of the experiment. It did not resist even the first wilting when the soil was dried to 7% of its W.H.C. **Colocynthis** resisted only the first and second wiltings when the soil was dried only to 7% of its W.H.C. It did not resist even the first wilting when the soil was dried to 5% of its W.H C. **Mesembrianthemum** proved to be more drought resistant than either **Colocynthis** and **Vicia**. It resisted the first and second wilting when the soil was dried both to 7% and to 5% of the total water-holding capacity.

The total bound water content was found to increase as the plant gets hardened, by being subjected to repeated wilting. **Colocynthis** plants subjected to the first wilting possessed a total bound water content of 20.35% which increased to 26.67% after subjecting the plants to the second wilting. Similarly, **Mesembryanthemum** possessed a bound water content of 21.77% which increases to 28.23% with repeated wilting in the 7% series; and 38.60% which increases to 40.56% in the 5% seriesi

An explanation of the increase of bound water under dry conditions was that in habitats, such ns the desert, where soil moisture is inadequate, the tissues of the plant are subjected to greater influences. The plant would consequently have a lower total water content of free water per gram of dry matter, and therefore, a higher percentage of bound water (Welch 1938). Another explanation was that accumulation of hydrophyllic colloids in cells takes place under dry conditions. This explanation has been warranted by various authors working on bound water, such as Rosa (1921) and Migahid /1945).

It would seem, therefore, that increased bound water content is both a result of, and an adaptation to drought whether it is a physiological or a real one.

The writer wishes to thank Prof, Migahid, A.M. for valuable help and for reading the manuscript.

SUMMARY

Hardening of the experimental plants against drought was brought about by subjecting **Vicia**, **Colocynthis** and **Mesembryanthemum** plants to repeated wilting. The plants were allowed from time to time to live for some days under conditions of deficient soil moisture. **Mesembryanthemum** and **Colocynthis** resisted that treatment and could survive while all **Vicia** plants perished during the experiment. It was found that this treatment increased the capacity of the plants for drought resistance and wilting endurance. Associated with that increase in drought resistance is an increase in bound water content. After the second wilting, the bound water content was found to be higher than after the first wilting.

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URANIUM AND THORIUM CONCENTRATION IN SOME SULFIDE AND OXIDE MINERALS FROM NON-URANIFEROUS AREAS

by

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INTRODUCTION

The object of the present paper is to determine the concentration and distribution of uranium and thorium in sulfide and oxide minerals. The present work is a part of a general plan to cover the concentration and distribution of uranium and thorium in minerals of various chemical groups.

Occurrence and emplacement of uranium in minerals take place in one of the following forms :

(1) the element may be distributed through the rock-forming minerals
(2) held in cation exchange positions.
(3) absorbed on the surfaces of crystals
(4) dissolved in fluid inclusions within crystals, or
(5) dissolved in intergranular fluids

Uranium and thorium concentration in the various sulfide and oxide minerals were determined by means of alpha - autoradiography

on nuclear emulsion plates. The technique described by Ghozlan (1956), and in detail described by Yagoda (1949) was followed.

SUMMARY OF THE TECHNIQUE USED

The samples used in the present work have been selected from a collection bought from Ward's Establishment, and from identified samples of known localities (local and foreign). The local samples were collected by the senior author during his various field trips.

Few grams of the mineral were crushed to powder and then put in a small watch glass (diam. 5 cms). The surface of the powder, after establishing radioactive equilibrium, was exposed directly to nuclear photographic plate for two weeks. The plates were then developed, and then fixed in a strong hypo-solution, washed in running water for several hours, and then left to dry. The plates were then fixed in special frames and rubbed with xylol, and then some cedar oil was put on each. The plates prepared in this manner, were tested under the microscope, using high-power objective and immersion oil as a medium of refraction between the plate and objective (total magnification 450 X). Alpha tracks appear as straight lines in three dimensions or as stars. The horizontal projection of such tracks is measured by means of the microscope's fine adjustment. The true length and true depth of the tracks were then calculated taking into consideration the shrinkage of the emulsion. After counting the number of these alpha tracks and measuring the length of each, the average ranges were computed. From this average range the quantity of the radioactive element was determined, whether uranium or thorium. The kind of radioactive element was then determined by determining the specific activity $T\alpha$ and the special formula for that (Ghozlan, 1956):

$T\alpha = 22\ U\ \Psi$ for uranium-bearing ores

$T\alpha = 6.9\ Th\ \Psi$ for thorium-bearing ores

where $T\alpha$ is the alpha track density (number of alpha tracks / cm^2 of photographic plate).

U, Th Uranium and thorium content in one gram of sample.

Ψ is the permeability of the medium (mineral).

URANIUM AND THORIUM CONCENTRATION

Tables 1 a, 1 b, and 1 c. give the serial nnmber of the samples analyzed, name, chemical formula, type, U ar Th concentration, and locality of the minerals tested arranged according to their chemical composition into the following three groups, namely sulfosalts, sulfides, and oxides, respectively.

Table 1 a : Sulfosalts

Serial No.	Mineral name	Chemical formula	Type	U conc. ppm
1	Enargite	Cu_3AsS_4	A_3BX_4	2.100
2	Boulangerite	$Pb_5Sb_4S_{11}$	ABX_2	0.695

Localities : 1, Cerro de Pasco, Peru; 2, Stevens County, Washington.

Table 1 b : Sulfides

Serial No	Mineral name	Chemical formula	Type	U conc. ppm
3	Chalcocite	Cu_2S	A_2X	1 .570
4	Chalcopyrite	$CuFeS_2$	AX	10.300
	(minor bornite)	(Cu_5FeS_4)	(A_3X_2)	
5	Chalcopyrite	$CuFeS_2$	AX	4 .520
6	Pyrrhotite	$Fe_{1-x}S$	AX	0 .633
7	Cinnabar	HgS	AX	2 .220
8	Cinnabar	HgS	AX	0 .775
9	Orpiment	As_2S_3	A_2X_3	14.400
	(with realger)	(AsS)	AX	

cont.

Table 1 b (continued)

Serial No	Mineral name	Chemical formula	Type	U conc. ppm
10	Stibnite	$Sb_2 S_3$	A_2X_3	0.452
11	Stibnite	$Sb_2 S_3$	A_2X_3	0.753
12	Pyrite	FeS_2	AX_2	1.720
13	Arsenopyrite	FeAsS	AX_2	0.350
14	Galena	PbS	AX	0.227
15	Galena	PbS	AX	0.137
16	Sphalerite	ZnS	AX	2.960
17	Sphalerite	ZnS	AX	0.792

Localities: 3, Katanga; 4. Wadi Hammash, Eastern Desret; 5, Monti peloritani, Sicily; 6, Monti Peloritani, Sicily; 7, Terlingua, Texas; 8, Almaden, Spain; 9, Near Madhattan, Nevada; 10, Sevier County, Arkansas; Kremitz, Hungaria; 12, Park City, Utah; 13, Anglesea Township, Ontario, Canada; 14, Monti Peloritani, Sicily; 15, Monti Poni, Sardinia; 16, Monti Peloritani, Sicily; 17, Balmat, New York.

Table 1 c : Oxides

Serial No	Mineral name	Chemical formula	Type	Comc. ppm U	Th
18	Zincite	ZnO	AX	2.380	
	(with franklinite)	$ZnFe_2O_4$	ABX_2		
19	Hematite	Fe_2O_3	A_2X_3		3.360
20	Hematite	Fe_2O_3	A_2X_3		15.200
21	Ilmenite	$FeTiO_3$	A_2X_3		414.000
22	Cassiterite	SnO_2	AX_2	3.360	
23	Cassiterite	SnO_2	AX_2	8.400	
24	Psilomelane	$BaMnMn_8O_{16}(OH)_4$	AX_2	32.400	
25	Goethite	$HFeO_2$	ABX_2		90.500

Localites: 18, Franklin, New Jersey; 19, Cumberland, England; 20, Aswan ore, Aswan; 21, Black sand, Rosetta, Egypt; 22, Cornwall, England; 23, El Igla, Eastern Desert; 24, New South Wales; 25, pseudomorphs after pyrite, Kharga Oasis, Western Desert.

TABULATION OF RESULTS

Tablec 2 a, b, c, and d list uranium and thorium concentration in the teste minerals, according to the following groups: less than 1 ppm, 1-10 ppm, and 10-100 ppm.

Tabele 2 a : Uranium concentration in sulfosalts

Less than 1 ppm		1-10 ppm		10-100 ppm	
Sample No.	U ppm	Sample No.	U ppm	Sample No.	U ppm
2	0.695	1	2.100	—	—

Table 2 b : Uranium concentration in sulfide minerals

Less than 1 ppm		1-10 ppm		1-100ppm	
Sample No.	U ppm	Sample No.	U ppm	Sample No.	U ppm
6	0.633		1.570	4	10.300
8	0.775	5	4.530	9	14.400
10	0.452	7	2.220		
11	0.753	12	1.720		
13	0.350	16	2.960		
14	0.227				
15	0.137				
17	0.792				

Table 2 c : Uranium concentration in oxide minerals

Primary oxides				Secondary oxides			
1 — 10 ppm		10 — 100 ppm		1 — 10 ppm		10 — 100 ppm	
Sample No.	U ppm	Sample No.	U ppm	Sample No.	U ppm	Sample No.	U ppm
18	2.380	—	—	—	—	24	32.400
22	3.360	—	—				
23	8.400	—	—				

Table 2 d : Thorium concentration in oxide minerals

Primary				Secondary			
1 - 10 ppm		10 - 100 ppm		10 - 100 ppm		100 - 1000 ppm	
Sample No.	Th ppm	Sample No.	Th ppm	Sample No.	Th ppm	Sample No.	Th ppm
19	3.360			20	15.200	21	414.000
				25	90.500		

DISCUSSION OF THE RESULTS

From tables 2.a, 2.b, 2.c, and 2.d , the following remarks are noticed.

(1) The sulfosalts are very low in the uranium content (less than 2.1 ppm). The sulfides are also low in their concentration of uranium, 13 out of 15 minerals contain less than 10 ppm, 2 minerals contain uranium between 10 and 100 ppm (actually between 10 and 15 ppm). No thorium has been detected in either the sulfosalts or sulfides. Uranium occurs in the oxide minerals in quantities higher than in the sulfosalts and sulfides. Thorium occurs in the oxides.

These results are clearly noticed if we consider the mean values of uranium and thorium concentrations in the tested minerals. Table 3 gives the mean values (arithmatic mean) of uranium and thorium concentration in the samples studied.

(2) The sulfides tested are mainly primary sulfides (hydrothermal or pyrometasomatic origin). The oxides investigated, on the other hand, belong mainly to two genetic groups, namely: primary and secondary. The primary oxide minerals were found to have a lower uranium and thorium content than the secondary oxides. In the primary oxides the concentration is less than 5 ppm, while in the secondary oxides uranium concentration is about 32 ppm. Thorium concentration in the primary oxides in less than U concentration in same group of primary oxides. The high thorium content in the

Table 3 : Mean values of U, and Th concentration in the tested minerals.

Chemical group		Total No. of samples	Mean value U ppm	Mean value Th ppm
Sulfosalts		2	1.397	—
Sulfides		15	2.787	—
Oxides	Primary	3 (U)	4.713	—
		1 (Th)	—	3.360
	Secondary	1 (U)	32.400	—
		3 (Th)	—	173.233

secondary oxides (mean value 173 ppm, table 3) is due to the high content of thorium in the "Rosetta" ilmenite grains (414 ppm, tables 1 c, and 2 d). It has been noticed by the senior author, through microscopic examination that some ilmenite grains contain mechanical inclusions of monazite which explains the unusual high content of thorium in the oxide mineral ilmenite.

SUMMARY AND CONCLUSIONS

The low values of uranium concentration in sulfosalts and sulfide minerals, and relatively higher values in the oxide minerals agree well with the nature of uranium element, being an oxyphile element (occurs as oxides, hydroxides, oxygen salts, and silicates), and not a sulfophile one (does not occur naturally as native element, sulfides, arsenides, sulfosalts or tellurides).

The secondary oxide minerals contain relatively higher concentrations of uranium and thorium compared to the primary oxide minerals. In the case of higher uranium content in these secondary oxides, this may be attributed to the high mobility of the uranyl ion $(UO_2)^{2+}$ which preserves its identity ,in solution, and in which uranium is hexavalent that results readily from the oxidation of tetravalent uranium. The high thorium content in secondary oxidation of tetravalent uranium. The high thorium content in secondary oxides is mainly due to mechanical inclusions of thorium-bearing minerals, i.e. monazite in ilmenite.

The tested secondary oxide minerals containing uranium are mainly manganese oxides formed by deposition from solutions, either by replacement or open filling. The secondary oxide minerals containing thorium are hematite, goethite, and ilmenite.

Research is being carried at present to locate the sites of occurrence of uranium and thorium and thorium in the tested minerals. It is known that uranium or thorium may be emplaced in minerals in any of the following manners :

(1) The element may be distributed through the structure of the mineral.

(2) Held in cation exchange positions.

(3) Absorbed on the surfaces of crystals.

(4) Dissolved in fluid inclusions within crystals, or

(5) Dissolved in intergranular fluids'

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دار الشرق الأوسط للطباعة والنشر
٤ صدان عرابي اسكندرية ـ ت ٣٢٨٧١

ويتبين من ذلك ان تركيز اليورانيوم فى الكبريتيدات والأملاح الكبريتيه أقل منه فى حالة الأكاسيد وهذا يتفق مع طبيعة عنصر اليورانيوم الذى يميل إلى الأكسجين ولا يتفق مع الكبريت فى تكوين المركبات الكبريتية المختلفة .

وتحتوى المعادن الأكسيدية الثانوية على كميات من اليورانيوم والثوريوم اعلى نسبيا من تلك الموجودة فى المعادن الأكسيدية الأولية . ففى حالة اليورانيوم العالية التركيز يمكن أن يعزى ذلك إلى سهولة انتشار اليورانيوم سداسى التكافؤ فى صورة أيون اليورانيل فى المحاليل والناتج من تأكسد اليورانيوم رباعى التكافؤ . أما فى حالة تركيز الثوريوم العالية فى الأكاسيد الثانوية فيرجع ذلك إلى المكتنفات المعدنية الحاوية للثوريوم ، مثال ذلك وجود مكتنفات من المونازيت داخل الألمينيت .

ويجرى البحث حاليا لتحديد أماكن وجود اليورانيوم والثوريوم فى هذه المعادن . والمعروف أن اليورانيوم أو الثوريوم يأخذ مكانه فى إحدى الصور التالية :

(١) قد يوجد العنصر موزعا فى البناء الذرى للمعدن .

(٢) قد يكون موجودا فى أحد أماكن الاستبدال الكاتيونى .

(٣) ممتصا على اسطح البلورات .

(٤) ذائبا فى المكتنفات السائلة داخل البلورات ،

(٥) ذائبا فى السوائل بين الحبيبات .

كميات اليورانيوم والثوريوم فى بعض المعادن الكبريتيدية والاكسيدية من مناطق خالية من المعادن المشعة

للدكتور محمد عز الدين حلمى و الدكتور احمد ابراهيم غزلان

قام المؤلفان فى هـذا البحث بتعيين كمية اليورانيوم والثوريوم فى بعض المعادن الكبريتيدية والأكسيدية وذلك باستعمال الألواح النووية وتسجيلها لاشعاعات ألفا التلقائية .

لقد تم اختبار ٢٥ عينه مختلفة لمعادن تابعة للمجموعات الكيميائية : الأملاح الكبريتية ، الكبريتيدات ، الأكاسيد، وتعيين كمية اليورانيوم والثوريوم بها.

ويبين الجدول التالى المتوسط الحسابى لقيم تركيز اليورانيوم والثوريوم فى المعادن التى درست .

المجموعة الكيميائيه		العدد الاجمالى للعينات	متوسط تركيز اليورانيوم (جزء في المليون)	متوسط تركيز الثوريوم (جزء فى المليون)
الأملاح الكبريتيه		٢	١ر٣٩٧	—
الكبريتيدات		١٥	٢ر٧٨٧	—
أكاسيد	أوليه	٣ (يو)	٤ر٧١٣	—
		١ (ثو)	—	٣ر٣٦٠
	ثانويه	١ (يو)	٣٢ر٤٠٠	
		٣ (ثو)	—	١٧٣ر٢٣٣

الماء الحبيس فى النبات وعلاقته بتحمل النبات لظروف الجفاف

للدكتور محمد الشافعى على

أجرى هذا البحث على نباتات الفول والحنظل والفاسول الفورسكالى لدراسة مدى تأثير الجفاف على محتوى الماء الحبيس بأنسجة النبات ، وذلك بتعريض عينات من هذه النباتات مزروعة فى أصص لدرجات متفاوتة من الجفاف وتقدير الماء الحبيس فى كل حالة .

وتبين من البحث أن هذه المعاملات تزيد من مقدرة النبات على تحمل الجفاف وأن الماء الحبيس فى الأنسجة يزيد كلما زاد تعرض النبات لظروف الجفاف . كما تبين أن نبات الفول لم يستطع تحمل درجات الجفاف التى تعرض لها خلال التجربة على عكس نباتات الحنظل والفاسول الفورسكالى التى اجتازت هذه المعاملات بنجاح .

دراسات تقسيمية لنباتات « السد »

للدكتور محمد الشافعى على

تشغل منطقة « السدود » بأعالى النيل أحواض بحر الجبل وبحر الزراف وبحر الغزال وجزء من حوض السوباط وتنمو النباتات المائية فى هـذه المناطق بطريقة وبائية بحيث تكون كتلا نباتية هائلة تعوق سير الملاحة ومرور مياه النيل .

وقد أتيحت للكاتب فرصة القيام بدراسات بيئية وتقسيمية على الكثير من النباتات التى تنمو فى هـذه البيئات ، ووضع مفتاح للتمييز بين الأنواع المختلفة . واستعان الكاتب — بالاضافة إلى دراساته الشخصية — بالمعلومات التى وردت فى المراجع التى جاء ذكرها فى هذا البحث.

مرض ذبول القرع العسلى فى مصر

للدكتور يوسف عبد الغنى

يهدف هذا البحث إلى دراسة وتسجيل مرض ذبول القرع العسلى. فقد وجد أن مسبب هذا المرض هو الفطرة فيوزاريوم سولانى المعزولة من نبات مصاب ظاهر به أعراض المرض . ولاثبات ذلك زرع نبات القرع العسلى فى تربة ملقحة بمزرعة نقية من هذه الفطرة . وبدراسة أعراض هذا المرض وجد أنه يلون الأوعية الخشبية للنبات باللون البنى ، كما لوحظ اصفرار الأوراق يعقبه ذبول وفى النهاية يموت النبات .

كذلك درس الباحث صفات جراثيم هذه الفطرة على مزارع مختلفة . ووجد ان هذا المرض لا يصيب أى نبات من نفس الجنس غير القرع العسلى .

استعمال النمو الطولى للاغلفة الورقية "Coleoptiles"

لبعض النباتات النجيلية المصرية للكشف عن الهرمونات و مثبطات النمو

للدكتور حسن انور فوده و السيد / سمير احمد رضوان

يتضمن البحث كثيرا من التجارب التى أجريت على خمسة نباتات نجيلية مصرية هى : الشعير والذرة الشامية والقمح والذرة العويجة والأرز ، وذلك لمعرفة أنسبها لاستعمالها للكشف بيولوجيا عن الهرمونات ومثبطات النمو النباتية ، وأوضح البحث أنسب هذه النباتات كما بين أفضل الطرق التى يجب اتباعها عند القيام باجراء مثل هذا الكشف .

عن الفلورا الفطرية فى الصحراء المصرية فى الصيف

للدكتور صبرى حسن علوان

تناول هذا البحث الفلورا الفطرية لبعض النباتات وأنواع من التربة فى فصل الجفاف . ولقد ثبت أن المحيط الجذرى بيئة دقيقة فعالة فى المجتمع النباتى الصحراوى . وسجل وفرة أنواع « بنسيليوم » و « أسبرجاس » و « فيوزيريوم » . أما أنواع « أسبرجاس » فقد تم عزلها من من نوع من التربة ، بينما سجلت هذه وأنواع من « بنسيليوم » من النوع الآخر من التربة ، وبالنسبة لأنواع « فيوزيريوم » فقد تم عزلها عن المحيط الجذرى وليس من التربة . كما دل إمكان عزل جميع الأنواع من حول الجذور التى غسلت بطريقة تسلسلية على وجودها فى صورة فعالة نشيطة على هذه الجذور . ولقد نوقش احتمال وجود هذه الأنواع للتدليل على قدرة النباتات الصحراوية على مقاومة الجفاف . هذا وثبت أن الأعماق التى تصل إلى ٢٠ سم هى المناطق المنشطة لنمو الفطريات .

عزل فطريات تحلل السليلوز من تربة الحديقة

للدكتور محمد صابر نعيم

أمكن عزل عدة أنواع مختلفة من الفطريات التى تحلل السليلوز من تربة حديقة كلية العلوم بجامعة عين شمس بالعباسية ، القاهرة ، على أبعاد مختلفة من سطح التربة ، ومن أنواع متباينة من التربة ، وذلك على منابت غذائية آجارية تحتوى على السليلوز كمصدر كربونى ، وعلى مصادر نيتروجينية مختلفة . وقد عرفت معظم الفطريات المعزولة كما هو وارد فى البحث .

دراسـات على المواد الطبيعية المثبطة للنمو

المستخلصة من بذر المشمش

للدكتور حسن أنور فوده و السيد / سمير سيد احمد رضوان

استخلصت وفصلت المواد المثبطة للنمو الموجودة ببذور المشمش الكامنة وأجريت عليها تجارب بيولوجية لتوضيح أهميتها ودورها بالنسبة لظاهرة الكمون ، وأمكن استخلاص مجموعة إنزيمية من بادرات المشمش التى لهـا القدرة على تحطيم المواد المثبطـة للنمو الموجودة ببذور المشمش الكامنة . ويتضمن البحث مناقشة علمية لكل النتائج .

المواد المنظمة للنمو وكمون بذور المشمش

للدكتور حسن أنور فوده و السيد / سمير سيد أحمد رضوان

يتضمن البحث دراسة التغيرات التى تطرأ على المواد الطبيعية المنظمة للنمو أثناء نمو وإنبات بذور المشمش ، فاستخلصت وفصلت هذه المواد ودرست بيولوجيا ، ويوضح البحث مدى الدور الذى قد تلعبه مثبطات النمو الطبيعية بالنسبة لظاهرة كمون بذور المشمش ، ويتضمن البحث كذلك العوامل المختلفة المؤثرة على كمون بذور المشمش ومدى تأثيرها على المواد الطبيعية المنظمة للنمو ، ويشتمل البحث بالاضافة إلى ذلك مناقشة علمية لكل النتائج التى حصل عليها .

دراسات على الدهن الكلى فى جسم الحيوان الصحراوى الثديي

جاكيولس جاكيولس

للدكتور منير السيد احمد جبر و الدكتور عبد العظيم عبد الله شلبى

لقد اظهر هذا البحث على الحيوان الصحراوى الثديي جاكيولس جاكيولس ، فى فصول السنة المختلفة وتحت ظروف مختلفة من التغذية ، بأن المواد الدهنية الموجودة فى جسم الحيوان يمكن اعتبارها احد المصادر التى تمد الجسم بالماء ، وذلك عن طريق أكسدتها . كما دل البحث على أن تلك المواد الدهنية تمد الحيوان بالطاقة اللازمة عند تعرضه لحالات الجوع .

إزالة أغشية بويضات الضفدعة المصرية بواسطة البروتينيزات

للدكتور عبد الحليم كامل و الدكتور عز الدين سعيد حسين

تغلف بويضات البرمائيات عادة اغشية زلالية علاوة على الغشاء المحى . ولهذه الأغشية وظائف مختلفة منها حماية البويضات . وقد يتطلب معرفة فائدة هذه الأغشية مقارنة أجنة ناتجة من بويضات محتفظة بهذه الأغشية مع أجنة قد نزعت عنها هذه الأغشية . ويتطلب هذا طبعا ابتكار الطرق اللازمة لازالة هذه الأغشية مع المحافظة على سلامة البويضات بعد أن اتضح ان الطرق الميكانيكية او الكيماوية المتبعة تحدث اضرارا بالبويضات نفسها . ولهذا حاول المؤلفان استخدام الطرق الحيوية لازالة هذه الأغشية عن طريق الانزيمات المعروفة بهضمها للبروتينات .

وبدأت هذه التجارب بدراسة تاثير اربعة من الاندوبيبتيديزات المعروفة وهى البيبسين والتربسين والبنكرياتين والباباين على هذه الأغشية ، وقد لوحظ ان الأخير فى وجود المنشطه أزال هذه الأغشيه بعد اربعين دقيقة فى الرقم الايدروجينى ٥ر٥ .

وقد وجد ان الباباين المنشط بايدروكلوريد السيستين يزيل هذه الأغشية فى الرقم الايدروجينى ٨ الذى لم يتمكن الباباين وحده ـ أى بدون المنشط ـ من أحداث الازالة . إلا ان المنشط وحده استطاع فى هذا الرقم الايدروجينى من إزالة هذه الأغشية فى ثلاث ساعات الذى يدل على ان هذه الأغشية بها إنزيم الأنسجه ـ الكاثبسين ـ ولكن فى صورة غير نشطه . ولهذا ظهر فعله فى وجود المنشط .

وقد فحص تأثير إزالة الأغشية على نمو الأجنة بمقارنتها بأجنه بويضات محتفظة بأغلفتها وقد تبين ان الكاثبسين المنشط بايدروكلوريد السيستين وكذلك الباباين المنشط بالثايوجليكولات لهما اقل تأثير على الأجنة . وان الباباين المنشط بسيانور البوتاسيوم له تأثير قاتل بالنسبة لجميع البويضات . وان عدد الأجنة الشاذة التى تنتج مع استعمال ايدروكلوريد السستين او الجلوتاثيون لتنشيط الباباين عالية نسبيا .

ولوحظ أيضا ان البويضات المغلفه باغشيتها فقست عن اجنة طبيعية فى محلول يحتوى على تركيز ضئيل من سيانور البوتاسيوم فى حين ان فقس البويضات المنزوع عنها أغشيتها فى مثل هذا التركيز ماتت جميعا ولعل فى هذه التجربة يمكن البرهان ـ كما نعتقد على الوظيفه الوقائية للاغشية الزلاليه ضد السموم الكيماويه .

تأثير بعض المواد السامة للخلية على أجنة الدجاج

للدكتور عبد الحليم كامل

درس المؤلف تأثير ثلاث مركبات من مركبات الكينون وهى :

١ : ٤ نافتوكينون وفينانثرين كينون وبارابنزوكينون .

وذلك بتحضير محاليل مختلفة من المواد ثم بحقنها فى بيض الدجاج بعد وضعه فى الحضانة لمدة ٢٤ ساعة كما ان بعض البيض ترك لينمو دون حقن حتى يسهل ملاحظة ما طرأ من التغييرات نتيجة لتأثير هذه المواد .

وضع البيض الحديث الوضع فى الحضانة وترك لمدة ٢٤ ساعة ثم قسم هذا البيض إلى ثلاث مجموعات وعولجت كل مجموعة باحدى هذه المواد الثلاث التى مرت من كل منها هذه التركيزات :

١ : $١٠^{٥}$ ، ١ : ٥ × $١٠^{٤}$ ، ١ : ١٢٥ × $١٠^{٢}$ وقد تم الحقن كما يأتى :

عملى ثقب فى القشرة ثم حقنت بمقدار ١ سم من أحد المحاليل وهكذا كانت كل مجموعة من البيض محقونة بأحد هذه المواد من كل المحاليل المحضرة ذات التركيزات المختلفة . ويلاحظ عند الحقن أن يكون فى الزلال بالقرب من القرص المنبت بقدر الامكان . حتى إذا تم حقن كل البيض وضع مرة ثانية فى الحضانة لمدة ٢٤ ساعه أخرى دون أن يترك لمدة ٢٤ ساعة اخرى فى درجة حرارة الغرفة كما يفعل ودنجتون (١٩٥٥) وذلك حتى لا يتعرض البيض لبعض التلف إذا ترك المدة الطويلة فى هذه الدرجة المنخفضة من الحرارة :

ثم بعد انتهاء مدة ٢٤ ساعة أخرى — أى أن كل المدة التى قضاها البيض فى الحضانة هى ٤٨ ساعة — كان يفتح البيض ويفرد الجنين على الشريحة ويثبت « بالبوان » ثم يصبغ بالبوراكس كارمين ثم يدرس وتؤخذ له صورة فوتوغرافية يحضر بعدها لعمل قطاعات عرضية لدراسة التغييرات المختلفة التى تمت نتيجة ... ن .

وقد وجد أن هذه المركبات الثلاث لها تأثير مهبط للنمو .

وان الأنسجة التى تأثرت كثيرا هى النسيج العصبى ثم إلى حد ما النسيج الدموى ونسيج الميزودرم وان أكثر المواد تأثيا كان ١ :

دراسات كيماوية على بلازما الانسان المعالجة بالكاولين

للدكتور منير السعيد احمد جبر و الدكتور يسرى السعيد احمد جبر

والسعيدة / رجاء على

يتلخص ما جاء فى هذه الدراسة بأن معالجة البلازما بالكاولين ليس له تأثير ملحوظ على تركيز الصوديوم والبوتاسيوم فى البلازما وكذلك ليس له تأثير على الرقم الهيدروجينى وتركيز نيتروجين المواد الغير بروتينية ونسبة الألبيومين ـ جلوبيولين . ومعالجة البلازما بالكاولين يسبب نقص ملحوظ فى تركيز البروتين فى البلازما . بينما نسبة البوليببتيد فى البلازما تزداد بصورة ملحوظة . هذه الزيادة فى نسبة البوليببتيد يمكن ان ترجع إلى تفتت بعض البوليببتيد من بروثرومبين البلازما الذى تحول إلى ثرومبين نتيجة التأثير السطحى للكاولين .

ومثل البلازما العادية ، وجد أن حفظ البلازما السائلة المعالجة بالكاولين وتحت درجة حرارة الغرفة لايسبب تغير فى الرقم الهيدروجينى وتركيز كل من نيتروجين المواد الغير بروتينية وكل من الصوديوم والبوتاسيوم فى البلازما . كما وجد أن التركيز الكلى للبروتينات ينقص وتزداد نسبة البوليببتيد فى كل من البلازما العادية والبلازما السائلة المعالجة بالكاولين والمحفوظتان لمدة ستة شهور فى درجة حرارة الغرفة . ووجد ان نسبة الألبيومين ـ جلوبيولين المعينة بطريقة الاليكتروفور الورقى فى نقص متزايد باستمرار مدة حفظ البلازما فى تلك الشهور الستة ، وهذا بعكس النتائج المعينة بطريق الأليكتروفور . وتعليل ذلك راجع إلى زيادة قابلية سلاسل البيتيد المتحورة للصباغة .

دراسة هستوكيماوية على توزيع إنزيم سكسينيك ديهيدروجينيز

فى الأجسام السبحية للمحار

للدكتور فهمى ابراهيم خطاب

يتضمن هذا البحث دراسة العلاقة بين توزيع الانزيم التنفسى سكسينيك ديهيدروجينيز والأجسام السبحية فى الخلايا العصبية للعقد العصبية والمخية والقدمية والحشوية فى المحار .

وقد اتضح من هذه الدراسة أن نشاط هذا الانزيم ينحصر أساسيا داخل الأجسام السبحية لهذه الخلايا ، كما اتضح أيضا وجود بعض اختلافات فى نشاط هذا الانزيم بين الخلايا العصبية المختلفة .

دراسات على الغدد الصم فى البرمائيات

أ — الغدة النخامية فى الضفدعة المصرية الرقطاء

للدكتور وليم رزق الله

يتناول هذا البحث دراسة هستولوجية للغدة النخامية فى الضفدعة المصرية الرقطاء . وقد ميز المؤلف فى هذه الغدة منطقتين أساسيتين هما المنطقة الغدية والمنطقة العصبية ، ثم أثبت أن المنطقة الأولى تتميز إلى ثلاث مناطق تحتوى كل منها على أنواع خاصة من الخلايا استطاع أن يوضح وجودها باستخدام أصباغ خاصة .

دراسة كفاءة التأثير الفوتوغرافى لاشعاعات جاما

على أنواع متعددة من الأفلام الحساسة

للدكتور كمال الدين عبد العزيز محمود و الدكتور محمد عبد الخالق محروس

والسيد / عبد الفتاح عياد

استخدم فى هـذا البحث ثلاثة أنواع من الأفلام الحساسة (كوداك ـ أدوكس ـ الفورد ١ ، ٣) .

ولقد قيس تأثير مجموعة من إشعاعات جاما ذات طاقة تبدا من ٦٦٧ر٠ مليون الكترون فولت المنبعثة من السيزيوم ١٣٧ حتى ٢٥ر١ مليون الكترون فولت وهو متوسط الطاقة الجامية المنبعثة من الكوبلت ٦٠ وذلك تحت ظروف متباينة من التركيز للمظهر المستخدم .

كما درس تأثير تغير درجة تركيز المظهر على شكل المنحنى المميز للافلام المستخدمة وثبت أن تغيرا محسوساً لوحظ عند استخدام طيف متعدد الطاقات مثل طيف الراديوم ٢٢٦ .

كما درس تأثير تغير درجة حرارة المظهر على شكل المنحنى المميز لأنواع الأفلام المستخدمة .

تأثير بعض المبيدات الحشرية على النمل النجارى المصرى

« كمبونوتس ماكيولاتس إجيبتياكس »

للدكتور عبد العزيز عبد الحافظ سليمان و السيد / محمود نظيم شحاته

تم فى هذا البحث دراسة تأثير بعض المبيدات الحشرية على النمل النجارى المصرى وفيما يلى أهم النتائج العملية التى حصلنا عليها .

١ — عند وضع المبيد فى جرعات على ورقة ترشيح بطريقة « الالتصاق أو الالتقاط » وتقدير الجرعة السامة بعد ٢٤ ساعة عند مستوى ٥٠ ٪ للموت ، أمكن ترتيب المبيدات التى استخدمت ترتيبا تنازليا كالآتى :

سادس كلوريد البنزين ، ديالدرين ، بارائيون ، ألدرين ، كلوريدين ، توكسافين ، سيفين ثم د. د. ت.

٢ — عند وضع المبيد فى جرعات على السطح الخارجى لجسم النملة الشغالة وتقدير الجرعة السامة بعد ٢٤ ساعة عند مستوى ٥٠ ٪ للموت أمكن الحصول على الترتيب الآتى :

سادس كلوريد البنزين ، ديالدرين ، بارائيون ، توكسافين ، الدرين ، كلوردين ، د. د. ت. ثم سيفين .

٣ — عندما قدرت الجرعة السامة بعد ٢٤ ساعة عند مستوى ٩٥ ٪ للموت ، أمكن ترتيب المبيدات الثمانية ترتيبا تنازليا كالآتى :

أ — <u>باستخدام طريقة « الالتقاط » :</u>

سادس كلوريد البنزين ، بارائيون : ديالدرين ، الدرين ، د. د. ت. ، كلوردين توكسافين ثم سيفين .

ب — <u>بوضع المبيد على السطح الخارجى لجسم النملة :</u>

سادس كلوريد البنزين ، بارائيون ، د. د. ت. ، ديالدرين ، كلوردين ، الدرين ، توكسافين ثم سيفين .

يتبين من ذلك أن النمل النجارى المصرى « كامبونوتس ماكيولاتس » شديد الحساسية لمبيد سادس كلوريد البنزين ويلى هذا المبيد فى تأثيره وسميته للنمل الديالدرين وكان أقل المبيدات التى استخدمت تأثيرا عليه هو السيفين . ولذلك نوصى نتيجة لنتائج الدراسة الحالية بسادس كلوريد البنزين لمقاومة هذا النمل . وفيما يختص بأفضل الطرق لاستخدام هذا المبيد فى المعمل وفى الحقل والجرعات المناسبة فسوف يحتاج لتفصيل آخر من البحث .

حساسية الخنفساء السنمية ، جيبيوم بسيلودز سيزمب لبعض المبيدات عند درجات مختلفة من الحرارة والرطوبة

للدكتور عبد العزيز عبد الحافظ سليمان و الدكتور احمد كاشف

اختبرت حساسية الخنفساء السنمية جيبيوم بسيلويدز سيزمب لستة مبيدات حشرية بطريق الملامسة وهذه المبيدات هى : الملاثيون ، والباراثيون من المبيدات الفوسفورية ، والـ د. د. ت. واللينديين من المبيدات الكلوروهيدروكربونية ، والسيفين من مجموعة الكاربامات ، والبيريثروم من المبيدات النباتية .

وطبقا لمعامل الموت الخمسينى عند درجة حرارة ٢٦ م ودرجة رطوبة نسبية ٥٠ ٪ يمكن ترتيب تأثير هذه المبيدات على الحشرة المذكورة كالآتى : الباراثيون — اللينديين — البيريثروم — الملاثيون — السيفين ثم الـ د. د. ت.

وقد وجد أن سمية الملاثيون والباراثيون واللينديين والبيريثروم تزداد بارتفاع درجة الحرارة بينما تقل سمية السيفين والـ د. د. ت. بارتفاع درجة الحرارة .

أما درجة الرطوبة النسبية فليس لها تأثير يذكر على سمية هذه المبيدات .

دراسة مقـــارنة لسمية الـ د. د. ت.

والمالثيون للصرصور

للدكتورة سعاد أبو الفضل السيد

اتضح نتيجة لهذه الدراسة ما يأتى : —

١ — بناء على الاستقراءات فى تجارب استخدام المبيدات على حوريات إناث الصرصور الامريكى أنه بعد خمسة أيام من حقنها بمبيد الـ د. د. ت. أن جرعة معـامل الموت الخمسينى كان ٦ر٢ ملليجرام من المبيد لـكل جرام من وزن الجسم .

٢ — كانت جرعة معـامل الموت الخمسينى تحت نفس الظروف وباستخدام نفس الطريقـة على إناث الصرصور أيضاً فى حالة استعمال المالثيون ٣٥ر٠ ملليجرام فقط من المبيد لـكل جرام من وزن جسم الحشرة .

٣ — ثبت بناء على هذه النتائج أن سمية الماليثون أكثر سبع أضعاف من سمية الـ د. د. ت. لهذه الحشرة .

تركيز الجليكوجين فى بعض أنسجة الحيوان الثديى الصحراوى جاكيولس جاكيولس وعلاقته باقتصاد الماء فى جسمه

للدكتور منير السيد احمد جبر والدكتور عبد العظيم عبد الله شلبى

من المعروف ان احتراق مائة جرام من المواد الكربوهيدراتية ينتج عنها ٥٥٫٣ سم^{3} من الماء . وقد دفعتنا هذه الحقيقة إلى معرفة كمية الجليكوجين فى الكبد والعضلات الهيكلية (وهما اهم الانسجة التى تختزن الجليكوجين) ومدى استخدامه فى تزويد جسم الحيوان الصحراوى بالماء الناتج من عملية الاحتراق وقد ادت هذه الدراسة إلى ان الجليكوجين الموجود فى الكبد يستخدم فى فصل الصيف لتزويد جسم الحيوان بالماء لمواجهة الجفاف فى هذا الوقت من السنة .

دراسات على الكولسترول فى بلازما الحيوان الثديى الصحراوى جاكيولس جاكيولس

للدكتور منير السعيد أحمد جبر والدكتور عبد العظيم عبد الله شلبى

من المعروف أن أى تغيير فى تركيب غشاء الخلايا الحيوانية يؤثر على درجة نفاذية هذه الخلايا للماء والمواد الذائبة به . ولما كان الكولسترول من المواد الهامة التى تشترك فى تركيب غشاء الخلايا الحيوانية وبالاضافة لما هو معروف بأن زيادة تركيز الكولسترول فى بلازما الدم ينتج عنها ترسيب لتلك المادة على جدر الاوعية الدموية فى جمع الكلية ، دفعتنا كل هذه الحقائق ان إلى دراسة كمية الكولسترول فى بلازما الدم للحيوان الثديى الصحراوى جاكيولس جاكيولس وعلاقتها باقتصاد وأخراج الماء فى هذا الحيوان .

وقد أظهرت هذه الدراسة ان الكولسترول له علاقة باقتصاد الماء فى هذا الحيوان إذ ان كميته تزيد فى الصيف عنه فى الشتاء وتزداد كذلك فى الحيوانات التى تحت ظروف مائية سالبة مما يرجح أنه يترسب على جدر الشعيرات الدموية فى جمع الكلية مما يقلل من اخراج الماء.

الاستطارة المرنة للبوزيترونات بواسطة ذرات الهيدروجين في منسوب ٢س باستخدام طريقة المتغيرات

للدكتور على حلمى موسى

طبقت طريقة «كون» للمتغيرات التى ثبتت صحتها فى الطبيعة الذرية على الاستطارة المرنة للبوزيترونات بواسطة ذرات الهيدروجين فى منسوب ٢ س ، وذلك فى حدود طاقة ٥٤ الكترون — فولت ، وكانت النتائج مقاربة لتلك التى حسبت بواسطة الحساب العددى للمعادلة التفاضلية التكاملية عند إدخال تأثير الازدواج فى المناسيب (١ س — ٢ س — ٢ ب) ، ومخالفة لتلك التى حسبت عند إدخال تأثير الازدواج القوى .

شدة الاستطارة لتكوين البوزيترونيام فى الهيليوم

للدكتور على حلمى موسى

يضم هـذا البحث تحليلا نظريا وحسابيا لشدة الاستطـارة لتكوين البوزيترونيام فى غاز الهيليوم كدالة لزاوية الاستطارة وذلك عندما تكون طاقة البوزيترون ضعيفة .

وقد طبق فى هذه الحـالة « تقريب بورن » الذى يصلح للطـاقة الضعيفة ، كما حسب مقطع تكوين البوزيترونيام عند القيمة الحرجة للطاقة فوجد أنها ربع قيمتها المستنتجة افتراضيا (نظرا لأنها لاتمثل تفاعل طبيعى حقيقى) من التجارب العملية .

الفراغ ذو الأربعة متجهات وتعميم النظرية النسبية

للدكتور فهمى ابراهيم ميخائيل

ظهرت الحاجة إلى تعديل النظرية النسبية العامة وتعميمها فى أكثر من مناسبة ، وقد أجريت فعلا بعض التعديلات للنظرية لتحقيق أغراض مختلفة وبطرق مختلفة ، والبحث الحالى يعرض فكرة إجراء تعديل شامل للنظرية ليحقق جميع هذه الأغراض ، وذلك باستبدال الفراغ الريمانى الذى تعتمد عليه النسبية العامة بالفراغ اللاريمانى ذو الأربعة متجهات ، ولذلك قام المؤلف فى هذا البحث بدراسة جميع الخواص الهندسية لهذا الفراغ وإبراز العلاقات المختلفة لعناصره مما يجعله صالحاً لإجراء التعديلات المطلوبة .

المجموعات المحدودة ذات عنصرين مولدين

للدكتور كمال رياض يعقوب

في هذا البحث درس المؤلف المجموعات ذات عنصرين مولدين رتبة أحدهما ٩ وميز المؤلف بين المجموعات المتشابهة .

حلول المعادلة التفاضلية ص(ك) + س ص = ٠ بالتكاملات المحدودة

للدكتور كمال رياض يعقوب و الدكتور الفونس رياض يعقوب

استخدم المؤلفان طريقة جديدة لحل هذه المعادلة بواسطة التكاملات المحدودة وميزة هذه الطريقة أنها تعين عددا من الحلول يماثل رتبة المعادلة .

عن التحليل الثلاثى لتكاثر دوال شور

للدكتور راجى حليم مقار و السيد / محمد على سمرى

يتألف هذا البحث من جزئين ، يبحث الأول منها عن معامل دالة شور { ٧ م — ك — ر ، ك ، ر } حوث ك ≤ م ، فى التكاثر { م } ⊗ { لا } وحيث (لا) أى تقسيم للعدد ٧ . وقد أوجد هذا المعامل لجميع القيم ١ ≤ ر ≤ ك ≤ ٨ .

وفى الجزء الثانى قد اوجد معامل دالة شور {٨م — ك — ر، ك، ر} حيث ١ ≤ ر ≤ ك ≤ م ، فى التكاثر { م } ⊗ { لا } ، لجميع قيم ك ≤ ٨ ، حيث (لا) أى تقسيم للعدد ٨ ، وذلك باستخدام طريقة تكرارية عددية :

عن المصفوفة العكسية لمصفوفة جبرية صفوفها منتهية

الدكتور راجى حليم مقار والدكتورة حكمات محمد صقر

أ مصفوفة لا نهائية من درجة م ، صفوفها منتهية ، ولها مصفوفة عكسية ب كثيرة حدود فى أ .

د (ن) رقم العمود لآخر عنصر غير صفرى فى الصف النونى بالمصفوفة أ ، ى (ن) رقم العمود لآخر عنصر غير صفرى فى الصف النونى بالمصفوفة ب .

أ (ن) مقياس العنصر ذى أكبر مقياس فى الصف النونى من المصفوفة أ ، ب (ن) مقياس العنصر ذى أكبر مقياس فى الصف النونى من المصفوفة ب .

فى البحث الأول درس الباحثان تزايد الدالة ى (ن) مع تزايد الدالة د (ن) .

وفى البحث الثانى درس الباحثان تزايد الدالة ب (ن) مع تزايد الدالتين أ (ن) ، د (ن).

وتعتمد جميع النتائج فى البحثين على العدد م .

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